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FISKERIDIREKTORATETS SKRIFTER
Serie Havundersøkelser
(Reports on Norwegian Fishery and Marine Investigations)
Vol. X. no. 3.
Published by the Director of Fisheries

On the Geographical Variation in Growth and Sexual Development of the Deep Sea Prawn

(*Pandalus borealis Kr.*)

By
BIRGER RASMUSSEN

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Preface

The investigations on the biology of the deep sea prawn have been carried out intermittently through a number of years at the Directorate of Fisheries, Institute of Marine Research. The work has been made possible mainly by grants from the Research Fund of the Fishing Industry. I tender my best thanks to the Trustees of the Fund, and to the Director of the Institute of Marine Research, Gunnar Rollefsen, for the confidence reposed upon me and for the support given during the whole period of investigation. I also offer my thanks to Professor Johan T. Ruud for helpfull suggestions and criticism. And last, but not least, I am greatly indebted to the many prawn fishermen along the Norwegian Coast for their close cooperation while collecting material from a variety of prawn grounds. The fishermen often carried through their part of the work under most adverse conditions during the war 1940—1945.

Birger Rasmussen.

Introduction

The biology of the deep sea prawn, *Pandalus borealis* Krøyer, has been studied by several investigators. ALF WOLLEBÆK (1903) made the first attempt to describe the life history of this crustacean, and later authors as WILHELM BJØRK (1911), ALFREDA BERKELEY (1930) FERDINAND LEOPOLDSEDER (1934) and GØSTA JÄGERSTEN (1936) cast new light upon the biology of the deep sea prawn. The most important result of the investigations since 1930 is the discovery that the deep sea prawns are protandric hermaphrodites, i. e. the individual prawns are able to change their sex in such a manner that all or most prawns at first become sexually mature males and later in life egg-bearing females. After the change of sex the prawns remain females for the rest of their lives. This discovery of protandric hermaphroditism furnished a new basis for the study of the life history of the deep sea prawn. BERKELEY accounted for the growth of the prawn i n British Columbia on this new basis, and JÄGERSTEN in his report has similarly dealt with the deep sea prawn in the Gullmar Fjord, Sweden.

In Norway the work on the prawn was taken up by JOHAN HJORT and JOHANT.RUUD.In 1938 they published a comprehensive treatise on the "Deep Sea Prawn Fisheries and their Problems", covering the various aspects of the practical prawn fishery. They also summarized our previous knowledge of the biology of the deep sea prawn and published the results of their own investigations on the life history of the prawn in the Oslo Fjord and some other localities in Southern Norway.

In 1945 ERIK M. POULSEN published a report on the Danish prawn fishery in the Skagerak including his observations on the biology of the deep sea prawn in these waters.

The results of the observations by the various authors here mentioned show a high degree of uniformity with regard to the development and to rate of growth of the deep sea prawn. I shall here give a short outline of the life history of the deep sea prawn as described by HJORT and RUUD with particular reference to the conditions in the Oslo Fjord.

In the spring and early summer the full-grown female prawns gradually approach maturity. From the end of June and during July the ovaries grow in size and gradually assume a bluish green tint visible through the carapace. The prawns get "roe in the head" as the fishermen say. In the Oslo Fjord spawning begins in the middle of October and lasts throughout November. The ovigerous females carry their eggs throughout the winter. The eggs hatch through the whole of March and April and the first days of May. The spawning, and likewise the hatching, in the Oslo Fjord lasts for 1½—2 months, and the ovigerous period extends over approximately 5 months. The duration of these periods may, however, differ slightly in the various localities in the Skagerak area.

Upon hatching the prawn larvae measure about 5 mm. The larvae have a pelagic existence lasting for about 3 months. In this period they pass through 6 pelagic stages. After having attained, by the last moulting, a size of about 17 mm, and the appearance of the adult, they settle to the bottom.

In the middle of July the prawn trawl has caught larvae with a mean total length of 31 mm, the smallest individuals measuring only 21 mm. The prawns grow comparatively fast. Towards the end of December they have attained a size of about 65 mm. During winter the growth is somewhat slowed down. In early May when the prawns are one year old they have an average size of 78 mm. In the autumn, when the prawns are 1½ years old the mean size is 93 mm and the individuals have become sexually mature males. When the prawns reach an age of two years the following May, they measure on an average 105 mm, and in the autumn when 2½ years old the size is about 117 mm. The prawns are at this age sexually mature females and become ovigerous throughout the autumn. As long as the females carry their eggs, moulting cannot take place, and there is therefore no increase in size during the ovigerous period. The mean size of the prawns at the end of August the following year, when the prawns are about 3½ years old and are approaching a new ovigerous period, is appoximately 128 mm. Hjort and Ruud did not find it possible with any degree of certainty to trace the growth of the deep sea prawns in the Oslo Fjord any further.

In fig 1 is reproduced from the work of HJORT and RUUD the growth curve for the deep sea prawn. Besides the curve illustrating the growth in the Oslo Fjord as outlined above, observations from other localities are also represented. In Southern Sweeden(the Gullmar Fjord), the growth seems to be somewhat faster, but the difference is small. On the Pacific Coast (British Columbia) the growth rate as a whole is of the same order of magnitude as that found in the Oslo Fjord.

POULSEN (1945) states, that according to Danish investigations,

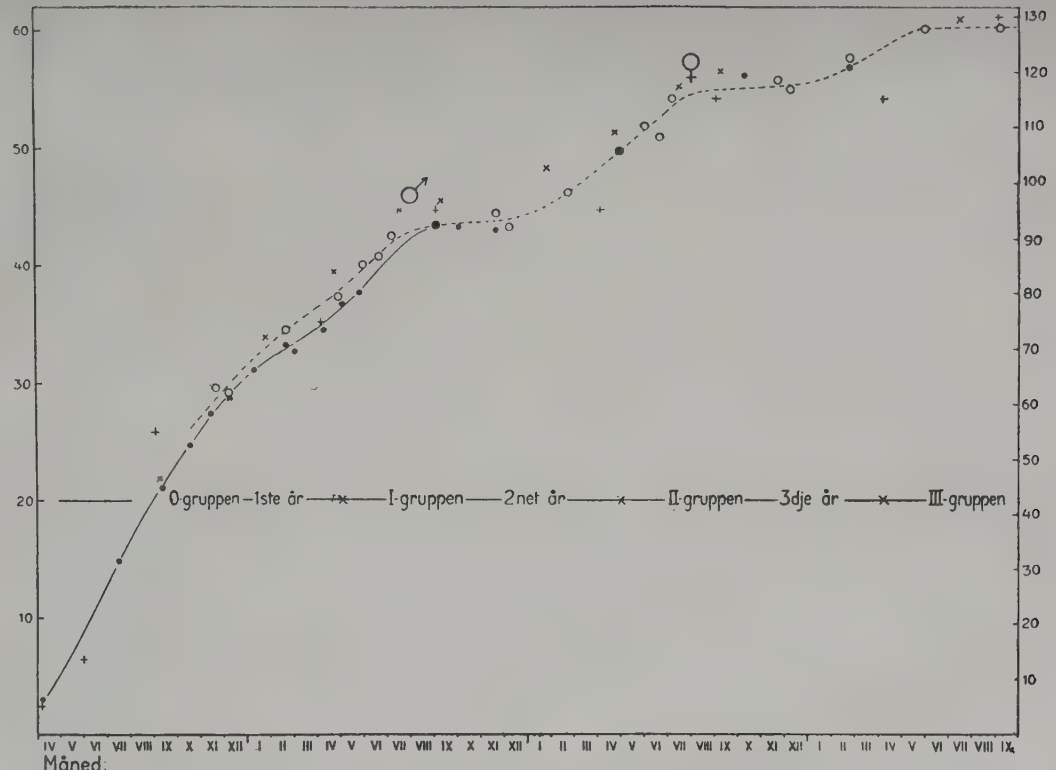

Fig. 1. The Growth Curve of *Pandalus borealis*. 0: Observations in different Localities in South Norway. 0: Observations on the Year Class 1933 in the Oslo Fjord. + Observations in British Columbia (Miss BERKELEY). × Observations in the Gullmar Fjord (JÄGERSTEN). Abscissa: Months. Left Ordinate: Carapace Length. Right Ordinate: Total Length. (from HJORT and RUUD).

the deep sea prawn in the open Skagerak, in regard to growth rate and change of sex, corresponds very closely with the prawn populations living in the fjords of the Norwegian and Swedish Skagerak Coast.

Earlier observations in other localities, particularly in northern waters, have indicated that we might expect a certain variation in rate of growth and sexual development of the deep sea prawn. Thus in Greenland waters ovigerous females have been found already in early September, and the eggs here do not hatch till April—May, possibly June (N. STEPHENSEN 1935). The ovigerous period should in other words extend over a period of 6—8 months, or 1—3 months longer than in the Oslo Fjord. According to observations by N. VON HOFSTEN (1916) ovigerous females have been found at the end of July and early August at Spitsbergen, in Northern Norway and in the Bearing Sea, which indicates an early spawning in these localities.

In the Balsfjord, Northern Norway CARL DONS (1914) found ovigerous female prawns from August to early April, a period of at least 7 months. HANS KJÆR (1903) had in the same fjord in the autumn found a prawn population consisting of 3 size groups. The largest individuals measured 12—15 cm and were females. This size distribution indicates a growth rate different from that found by HJORT and RUUD in the Oslo Fjord.

The general conclusion we may draw from the previous publications on this subject is, that in more southern localities although widely separated, the growth and sexual development of the deep sea prawn should largely be uniform, while in other parts, particularly in northern latitudes, the growth rate and the development into sexually mature females should possibly show different features.

In 1941 I had at my disposal several samples of deep sea prawns from Spitsbergen waters. While studying the report published by HJORT and RUUD I thought it would be of particular interest to utilize the Spitsbergen material for a closer investigation into the growth and development of the deep sea prawns in arctic waters using the prawns of the Oslo Fjord as a basis of comparison. After publishing a preliminary report in Norwegian on the deep sea prawn in Spitsbergen waters (1942) it was found desireable to extend the investigation to other prawning grounds. With grants from the Research Fund of the Fishing Industry a continued research programme was made possible.

The investigations into the biology of the deep sea prawn at Spitsbergen had shown that the growth and development of the species in these arctic waters were much slower than what had been found in Southern Norway. The idea was naturally born that the great difference found in the life history of these widely separated prawn populations

was due largely to evironmental factors. Variations in the temperature of the bottom water, the salinity, oxygen content and similar factors together with special topographical features of the individual prawning grounds might possibly influence the life history of the deep sea prawn. It was natural to pursue the investigations on the hypothesis that somewhere along the Norwegian Coast we might be able to find prawn populations which in their biological development might be different from those already studied.

In other words, the problem was to prove or disprove if there really existed a geographical variation in the growth and sexual development of the deep sea prawn in conformity with the theory that the farther north the prawns were found, the slower growth and maturing. In order to test the soundnes of the hypothesis a preliminary program for the collecting of prawn samples from various parts of the Norwegian Coast was drafted in 1942.

However, many difficulties arose on account of the war conditions in Norway. The plans had to be modified a great deal and could be realized only by degrees and over a comparatively long period of time. From 1943 prawn samples were systematically collected on the seasonal cruises of our fishery research ship "Johan Hjort". Later on contact was made with several fishermen engaged in commercial prawn trawling, fishermen who were willing to cooperate in the investigations by collecting prawn samples and giving the necessary information as to the topography of the prawn grounds and other details which were of interest from their practical point of view.

Through this cooperation with the fishermen we have been able to collect representative samples over a long period of time from various parts of the coast, a program which we would have been unable to carry through solely by means of our single fishery research ship.

Collecting and Handling of the Material.

The systematic collecting of prawn samples through active fishermen was started in 1944 and continuously carried on in one part of the coast or another till the spring of 1948. During the war it was impossible to contact the prawn fishermen in Finnmark in the northernmost part of Norway. After the war the prawn fishery has not as yet properly started in Finnmark, and no material has been available from this part of the coast. It would have been of great value if also these northern prawn grounds could have been properly examined.

Also in other parts of the country the prawn fishermen had difficulties during the war in carrying through their part of the sample collec-

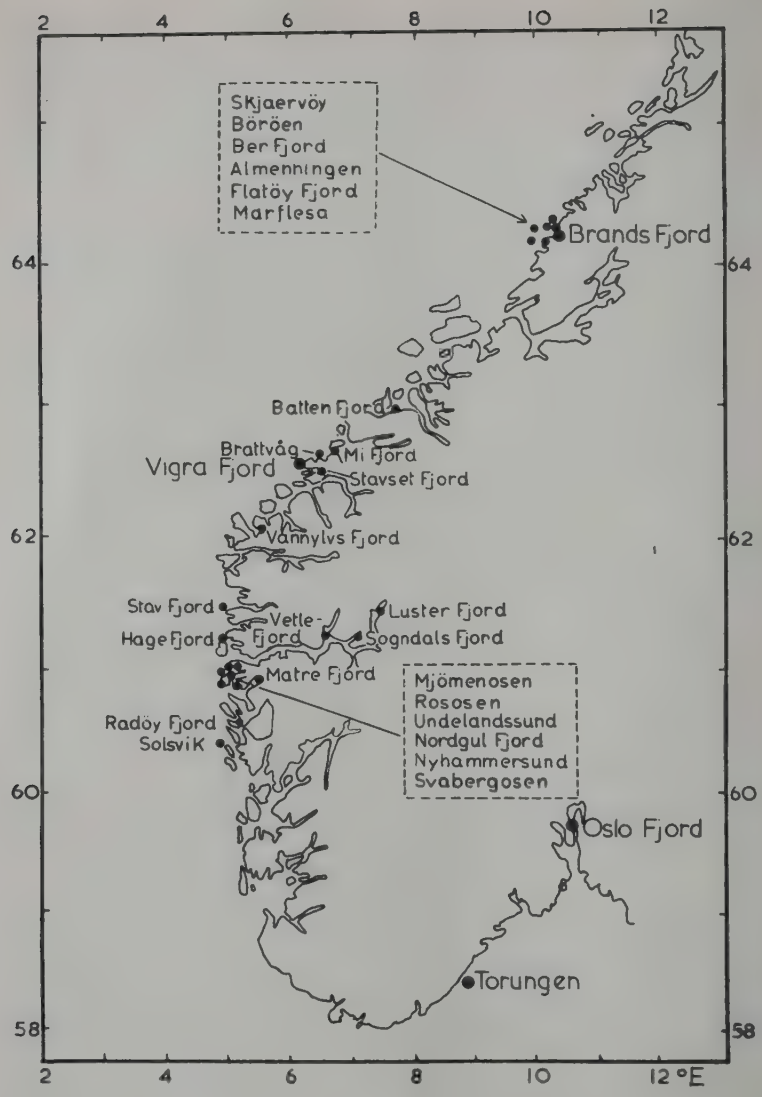

Fig. 2. Chart Showing the Localities in South and West Norway where Prawn Samples Have Been Obtained.

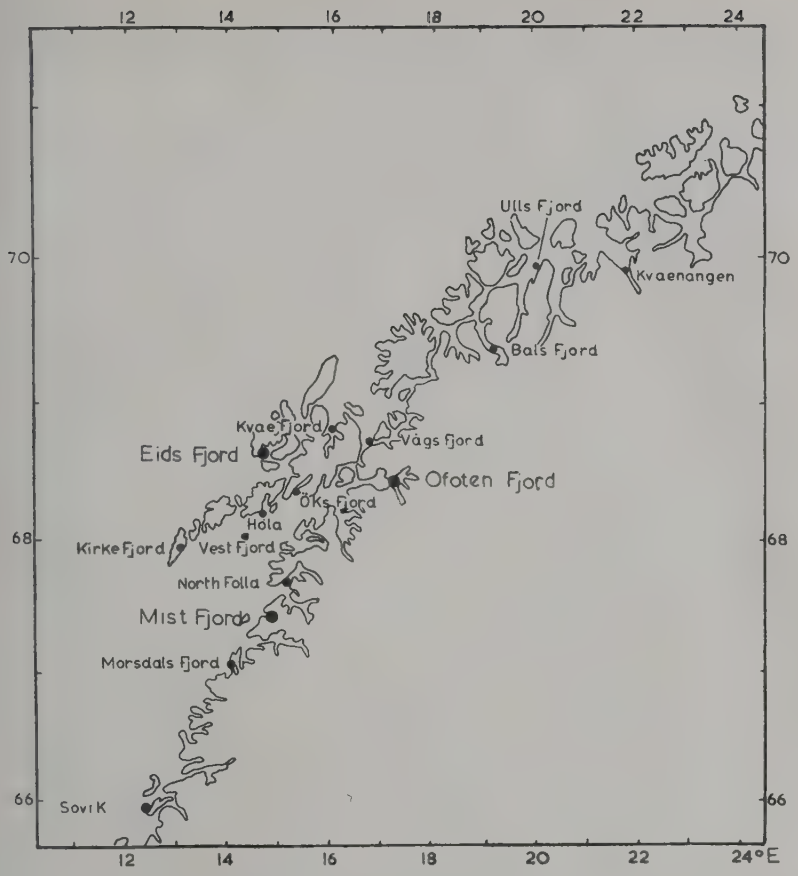

Fig. 3. Chart Showing the Localities in North Norway where Prawn Samples Have Been Obtained.

tion program. There was a great shortage of trawl gear, nets, repair twine and fuel oil for the engines, commodities which were strongly rationed and in certain periods impossible at all to obtain for the prawn fishermen. Our sample collection program was of course affected in no little degree by these conditions. Nevertheless, after several years we succeeded in obtaining material from the major part of the Norwegian Coast, i.e. between 58 and 70 degrees North latitude. The localities on the Norwegian Coast where prawn samples have been collected are shown in fig. 2 and 3.

The collecting of prawn samples were largely carried out according to the following scheme:

A prawn sample would generally contain 3—4 liters of prawns taken directly from the trawl immediately after the completion of the haul and before any sorting of the catch for the market had taken place. The fishermen were particularly notified that also the small unmarketable prawns should be included in the sample.

In some instances a fine-meshed net has been employed to cover the codend of the trawl in order to obtain satisfactory samples of the very small individuals which otherwise would escape through the ordinary mesh.

The samples were placed in a keg or a small barrel. With each sample was put down a label containing the necessary information as to locality of capture, date, depth, duration of the haul, total catch and type of trawl used. Experience proved that this information should preferably be written on good quality paper with india ink, as writing in ordinary ink or pencil, as well as low grade paper, dissolved in the preservative. For preservation of the prawn samples were used one part of formaldehyde to 10 parts of water, or one part of formaldehyde to 20 parts of water with enough salt added to make a briny solution. In this latter solution the prawns have been well preserved, retaining to a large extent their natural colour and pliability. The preservative was poured over the sample in the keg insuring that the prawns were well covered by the solution. If a fine-meshed covering had been used, the catch in the latter and that in the ordinary trawl were sampled separately. Before Before sending the keg to the Institute of Marine Research in Bergen the fishermen made certain that it was compactly filled and the lid securely fastened in order to avoid that the samples became mixed or put into disorder during transport.

The fishermen were informed that it was desirable to obtain a prawn sample every third or fourth week throughout the year, if the conditions permitted. This last point often proved difficult to carry through mostly due to war restrictions.

A preliminary analysis of the prawn samples disclosed that it might be desireable to confine the collecting to a single prawn ground in the fisherman's district. If samples from two or more different prawn fields were intermixed indiscriminately for the study of the growth rate in a limited area, a certain variation could be expected even between samples collected from adjacent prawn fields. The fishermen associated with the investigations were therefore later on asked to take the samples in one and the same locality if conditions permitted. In many cases this inter-

fered with their routine fishery as they ordinarily shifted from one prawn ground to another according to the season of the year.

At the laboratory the samples were treated in the following manner: The individual prawns were at first sorted into various categories according to their stage of development. The immature and male prawns are easily distinguished from the females by reason of the fact that the endopodite of the first pair of pleopods is developed as an organ of copulation with a different shape in the various categories of prawns (see fig. 4).

If the sample was taken in autumn, the presence of sperm in vasa deferentia indicated sexual maturity. In the female prawns the endopodite of the first pair of pleopods is pointed. The transition from males to females occurs through a number of moultings. The endopodite is changed a little through each moulting till it finally attains the pointed shape characteristic for the females. During the transformation from male to female we find 3 main transitional stages with endopodites as shown in fig. 4 (no. 5, 6, 7). On the Norwegian Coast these stages are usually found in early spring or in the winter on most prawning grounds, and they can quite easily be sorted out of the samples as "transitionals A, B, and C." When the prawns have passed through the various stages and reached stage "E", they can for a short period of time still be distinguished from older females having spawned before. The endopodite of the former has generally a more blunt and rounded point (fig. 4, no. 8).

As regards the females these have been sorted into various categories according to the state of ripeness, as for instance: females with — or without — mature ovaries, and berried females with eggs in different stages of development. After the last moulting before spawning in autumn the pleopods are richly covered with setae, and spawning can be judged to be imminent. These setae are also retained a short while, one or two weeks after the eggs have been hatched (BERKELEY 1930). The setae dissappear when the prawn has moulted after the hatching of the eggs.

When sorted in their various categories, the individual prawns have been measured. In earlier publications the total length of the prawns usually is recorded as measured to the nearest half centimeter. HJORT and RUUD measured the length of the carapace with the rostrum, and this measurement they recorded in millimeters. For the purpose of comparing their results with those of other authors they multiplied their figures by 2,15 which was the mean proportion between the total length of the prawn and the length of the carapace with the rostrum.

Upon sorting our own material preserved in formaldehyde it was found that only a small part of the prawns had an undamaged rostrum,

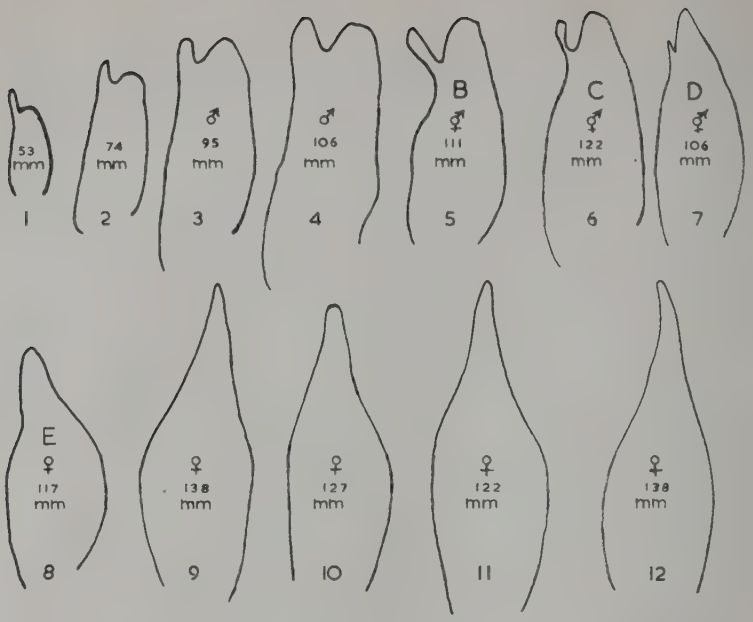

Fig. 4. The Endopodite of the First Pair of Pleopods (Setae Omitted) of *Pandalus borealis* in Various Stages of Development. 1—2: Immature Youngs. 3—4: Maturing Males. 5—6: Transition Stages from Male to Female. 8: Maturing Female after Transition (First Time Spawner). 9: Female Having Recently Hatched the Eggs and not Moulted. 10: Female having Moulted after Egg-bearing Period. 11—12: Female Rematuring after Previous Eggbearing Period.

and it proved impossible to measure them by the method employed by Hjort and Ruud. These authors had also tried to measure the carapace without the rostrum, but they found this procedure too tedious. This last method was, however, the only one which could be worked with any satisfaction on our material. With a sharply pointed compass the distance from the base of the eye to the posterior dorsal edge of the carapace has been measured, and the lengths recorded by placing the points of the compass on a millimeter scale (fig. 5). This method of measuring proved both rapid and satisfactory, and as had been the case with other methods, we succeeded in obtaining a clear grouping in the size distribution of these carapace measurements.

Hjort ane Ruud remark in their report that the total length can be measured with any degree of accuracy only on freshly caught indi-

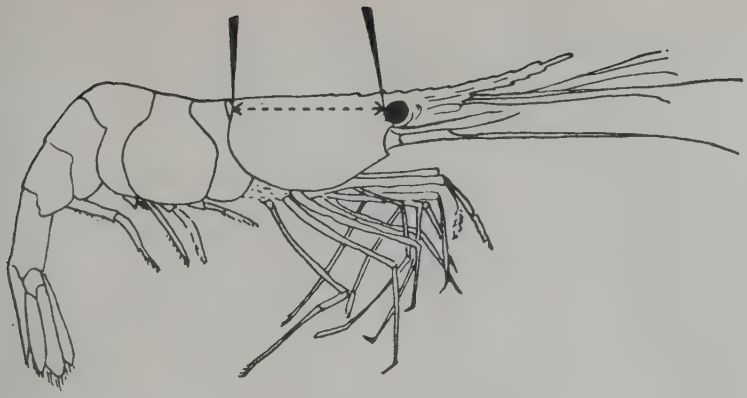

Fig. 5. The Method of Measuring the Carapace of the Prawn.

viduals, and they raise the objection against their own measuring method that the length of the rostrum varies to some extent in proportion to that of the body. By measuring only the carapace, as has been done with the present material, the individual variations in the size of the rostrum can be disregarded. In order to find the ratio of the total length of the prawn to the size of the carapace, control measurements have been taken on about 200 specimens from 5 different samples. This ratio was found to vary between the means of 5,25 and 5,40 in the different samples. When in the present report the total lengths of the deep sea prawns are given, these figures are arrived at by multiplying the length of the carapace by 5,3 which is the mean ratio arrived at through all control measurements.

Earlier investigations of the growth of the deep sea prawn have been carried out according to the "Petersen's method" by which the lenghts of a large number of prawns are measured. When these measurements prove to fall within a number of size groups, we are able to follow the growth of the prawn by repeated measurements at different times. The Petersen's method has also been employed in the present work in combination with the sorting of the prawns into various categories of maturity as described above.

The mean lengths calculated for the various size groups are naturally dependant upon a fairly correct division between each size group. Usually no difficulty is experienced in this respect as regards the youngest year classes. But the older year classes, particularly those comprising

females of varying age, often clash or overlap. In such cases it has been necessary to divide the groups by estimate, founded partly on the shape of the curve, and partly on the past history of development of the group.

Length-Weight Relationship.

In order to determine the length-weight relationship of the deep sea prawn a number of samples were handled particularly for this purpose. After sorting of the material and measuring of the individual prawns, the various size groups were segregated and weighed group by group. Later on the mean weight of the individual prawns were computed.

The weighing was performed on preserved material which had soaked in fresh water for 24 hours. The water was allowed to drain well off but the prawns were still moist when weighed. The material consisted of 10 samples taken throughout the year in the Oslo Fjord.

Small prawns of identical size showed little variation in weight from one sample to the other. The larger prawns, however, could differ widely in weight according to the season of the year and their state of maturity. Due to this variation in weight it proved convenient to divide the material in two parts according to sexual state. One part containing 4 samples (1533 individuals) covers the season of May 31st—September 13th 1944 when the prawns are not ovigerous. The other part containing 6 samples (2610 ind.), covers the egg-bearing period from November 27th 1944 till March 5th 1945.

The length-weight relationship of the deep sea prawn is shown in fig. 6. The prawns below 95 mm, which chiefly are males and youngs show quite uniform weights throughout the year. The larger individuals being mostly female have in the egg-bearing period considerably greater individual weights than what is found in individuals of identical size outside this season. For instance, a female prawn of 120 mm length has an average weight of 6,7 grams during the non-ovigerous period, while the weight for the same sized individual while carrying eggs is 8,5 grams. In larger individuals the weight difference during the two seasons is still greater.

Number of Eggs.

In connection with the weighing of the prawns and the result obtained, it was of interest to determine the number of eggs present in the various size categories of ovigerous prawns. The procedure employed

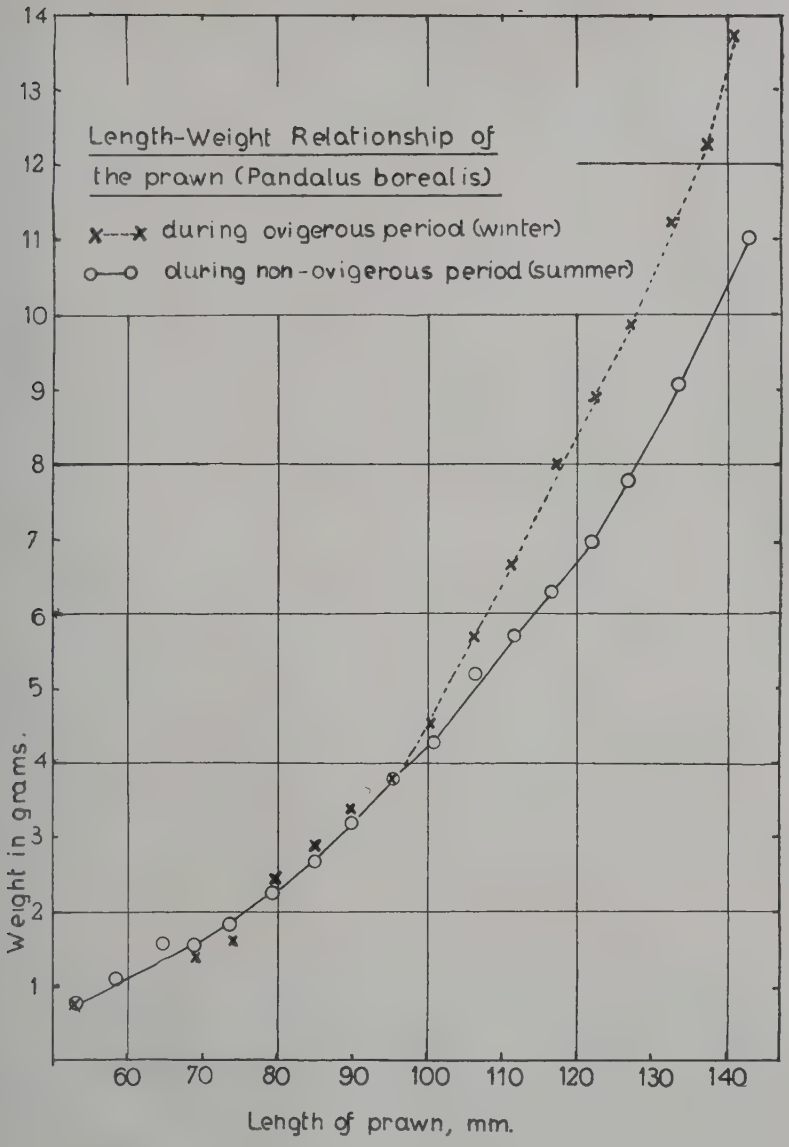

Fig. 6. The Length-Weight Relationship Curve for *Pandalus borealis*.

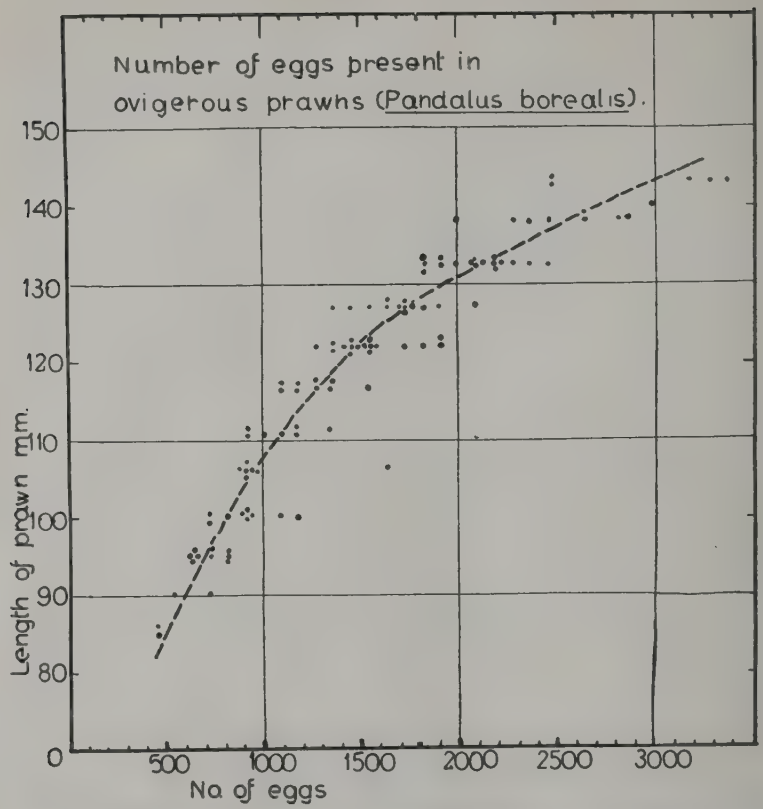

Fig. 7. The Relationship Between the Size of *Pandalus borealis* and the Number of Eggs Found in Ovigerous Females.

in counting the eggs was as follows: The moist eggs were carefully removed from the prawn, put into a 10 ml measuring tube with some water and centrifuged for 1 minute. The eggs were in this way lightly compressed towards the bottom of the tube and the volume of the egg mass could be measured to the nearest 1 10 ml. A total of 105 specimens were treated this way.

The number of eggs per ml was determined by 15 control countings throughout the winter. On the average 1 ml was found to contain 915 eggs. The prawn eggs have a slightly oval shape measuring approxi-

mately 1,1 × 0,9 mm. Fig. 7 shows the average number of eggs carried by prawns of different size. A small female of 85 mm length carries about 460 eggs. The number of eggs carried increases with increasing size of the prawn. A female measuring 120 mm, which is a common size of a prawn spawning as female for the first time, carries about 1450 eggs, while an older prawn of 140 mm will carry approximately 2700 eggs.

The Deep Sea Prawn of the Inner Oslo Fjord

As mentioned in the introduction HJORT and RUUD have reported upon the biology of the *Pandalus borealis* in their publication »Deep Sea Prawn Fisheries and their Problems«. The material treated by said authors was collected partly in the inner Oslo Fjord and partly in localities outside the fjord. In conjunction with my work on the life history of the deep sea prawn in various parts of Norway it was found desireable to obtain further material from the inner Fjord which for reason of comparison could be sorted and treated along the same lines as the material collected in other parts of the coast. Thanks to the kindness of Professor RUUD I was able to contact Mr. HAGBART HØIUM, a very capable prawn fisherman, who previously had assisted HJORT and RUUD in their work on the deep sea prawn. Mr. HØIUM agreed to collect a prawn sample once a month if conditions permitted, and the samples should all be taken at one and the same prawning ground. The ground chosen was the "Svartdjupet" (Black Deep). This prawning ground is a section of a complex system of prawning grounds in the western part of the inner Oslo Fjord called "The West Fjord". The locality where the samples have been collected is shown inside the black circle in fig. 8. This map is originally drawn by Mr. HØIUM and first published by HJORT and RUUD.

The Prawn Ground.

As regards the bottom configuration in general in this part of the fjord, we may cite from the same authors:

"The grounds in the West Fjord consist partly of deep channels and submarine valleys and partly of shelves. The shape of the grounds shows that the submarine tophography accords accurately with the tophography of the land of the western side of the fjord .... Many grounds are so narrow that it is necessary to navigate with the greatest accuracy according to bearings, and such grounds, therefore, can only be fished in clear

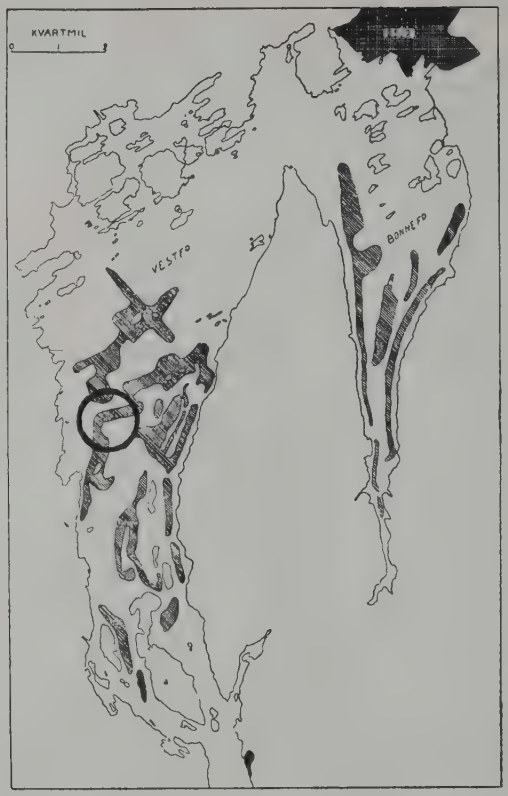

Fig. 8. The Prawn Grounds in the Inner Oslo Fjord (from Hjort and Ruud). The "Svartdjupet" is Situated Inside the Black Circle.

weather. Other grounds permit of greater deviations from the main course proper, but all of them are navigated according to bearings for the outer edges. The majority of the grounds which are marked off in the chart consists in reality of several continuous small grounds with different names for each course. In the West Fjord alone, between Steilene and Drøbak, there are thus 21 named grounds. To some extent these small grounds have been found either separately, and it was not until later that the possibility was discovered of trawling from the one

into another. Or they were found as branches of the large central ground during the work which was continually carried on in connection with the exploration of the latter. Some of the passages from one ground to another are so narrow that the boards can be felt gliding over rock or stone while only the trawl itself passes freely over the smooth bottom. At other places it is only possible to trawl one way from one ground on to another because the trawl is drawn from one shelf down on to another, and lower-lying."

To this description can only be added that the depth of the Svartdjupet is about 100 meters. The hydrographic conditions in the inner Oslo Fjord have been studied by several authors. JOHAN HJORT and H. H. GRAN (1900) found that the fjord had a definite nature of its own. The deeper water layers are cut off from communication with the corresponding layers of the Skagerak on account of the bar at the entrance of the fjord. The hydrographic character of the deep water of the fjord can remain unchanged for a considerable period of time. TRYGVE BRÅRUD and RUUD (1937) point out that an exchange of the deep waters of the inner basin only takes place when water from outside flows across the threshold, and when this water is heavier than the water masses located at the time in the deep strata of the inner basin. The waters of the deeper parts of the inner Oslo Fjord may be considered more or less stagnant. The renewal of the deep layers of the inner basin takes place at irregular intervals and is governed to a large extent by the movements of the surface water, which in turn depend upon the wind conditions

The surface layers down to about 40 meters are characterized by great changes during the year in temperature, salinity, and in oxygen, phosphate and plankton contents, while the deeper layers show very small changes. We may obtain a general idea of the conditions on the prawning ground of Svartdjupet by the study of the hydrographic stations taken by said authors. In table I are given the observations in the bottom layer at a depth of 95—98 meters off Steilene, a locality very close to Svartdjupet.

TABLE I. Oslo Fjord.

Date	Temperature °C	Salinity o/oo	Oxygen		Phosphate microgr.-atom P/l.
			ml/l	% sat.	
June 15. 1933	6,38	33,40	4,66	66,4	0,86
July 17. 1933	6,38	,30	4,28	61,2	1,18
Oct. 10. 1933	6,58	,04	2,84	40,7	1,37
Dec. 8. 1933	6,39	,60	4,93	70,6	0,69
Febr. 23. 1934	7,86	,31	4,15	61,1	0,99
April 9. 1934	6,55	,19	5,10	73,1	0,80
May 28. 1934	6,42	,15	3,99	57,0	1,14

In 1933—34 the bottom temperature varies between 6,38 and 7,86° C throughout the year, i. e. a range of 1,48° C. The oxygen content in the bottom water is very low in October but increases again in December by influx of water from the outside. The oxygen content is low again in May.

As mentioned above the renewal of the deeper layers takes place at irregular intervals, and the conditions tabulated can therefore hardly be expected to be repeated exactly along the same lines every year. However, the data give nevertheless a general idea of the conditions met with on this prawning ground in the Oslo Fjord. During the war, when the present material of the deep sea prawns was collected, no hydrographic observations were taken in the locality of Svartdjupet.

The Material.

The collection of prawn samples from the Svartdjupet commenced on May 31st 1944. In spite of adverse fishing facilities caused by the war conditions, the program of sampling was carried through in a satisfactory manner. This is solely due to the perseverence and generous interest of Mr. Høium. With a few unavoidable interruptions samples were collected steadily through 4 years till the spring of 1948. of prawns were collected steadily through 4 years till the spring of 1948. In this period 41 samples were collected containing a total of 17392 specimens. As far as possible one sample was collected every month. The distribution of the samples in the different years is shown in table II.

TABELL II. Oslo Fjord.

Date	No. of samples	No. of prawns
May—Dec. 1944	6	2468
Jan.—Dec. 1945	13	4741
Jan.—Dec. 1946	11	3078
Jan.—Dec. 1947	7	4618
Jan.—March 1948	4	2487
Total	41	17392

From October 1947 till March 1948 the sampling was done with a fine-meshed net covering the cod-end of the ordinary trawl. One sample was taken from the cod-end proper, another sample simultaneously from the fine-meshed covering.

Spawning and Hatching.

Investigations on the spawning of the deep sea prawn and hatching of the eggs in Southern Norway have previously been carried out by HJORT and RUUD. As regards the inner Oslo Fjord their investigations cover the spawning in the autumn of 1933 and the subsequent hatching of the eggs in the spring of 1934. According to these authors spawning commenced somewhat later in the inner Oslo Fjord than outside the fjord. In the inner part of the fjord less than one per cent of the females were ovigerous on October 19th, while a month later, on November 15th the majority of the prawns had spawned, but there were still some females who were not yet ovigerous. The authors conclude that spawning cannot have ended before the latter half of November 1933.

The present material from the prawn ground of Svartdjupet covers the spawning and hatching in four different seasons. As the material is from much the same locality as that of said authors it would be of interest to compare the conditions in regard to spawning some 10 years later. The sorting of our material gave the following results:

Spawning 1944: On September 11th the ovaries are maturing, but no spawning is observed. On November 27th 70 per cent of the females have spawned. A month later, on December 29th all females are ovigerous.

Spawning 1945: On August 23rd the ovaries are maturing, but no spawning is observed. On November 15th 55 per cent have spawned. On December 10th 97 per cent have spawned, while 3 per cent still have roe in the head. On January 1st all females are ovigerous.

Spawning 1946: On October 21st 76 per cent of the females are egg-bearing. On November 11th 71 per cent are egg-bearing, and on December 5th 91 per cent have spawned. On December 30th all females are ovigerous.

Spawning 1947: On October 13th 6 per cent of the female have spawned. On November 11th 33 per cent, and on November 28th 76 per cent of the females are ovigerous. On December 18th there are still two per cent of the females having "roe in their heads", while by January 1st 1948 all the females have spawned.

Apparently there is some variation from one year to another in regard to the commencement and duration of the spawning. Thus spawning seems to have started comparatively early in 1946 when the majority of the females are ovigerous as early as October 21st. As mentioned above HJORT and RUUD found in 1933 less than one per cent of the females that year ovigerous by October 19th. In 1947 the spawning commences during the first or second week of October, but the intensity of spawning is very low till the end of November.

Our material shows that spawning takes place sometime between the first half of October and the latter half of December, i. e. over a period of 2—2½ months. In most years 50 per cent seem to have become ovigerous by November 15th. As stated above the year 1946 shows exstraordinary conditions as spawning that year reaches that stage as early as October.

As regards the hatching of the eggs HJORT and RUUD remark that in 1934 hatching in the inner Oslo Fjord had commenced in February and was well on the way in March. On the second of March they found that 46 per cent of the females had hatched, but on May 2nd still 3 per cent of the females were carrying eggs. In later samples no ovigerous females were found.

Our material gives the following information on the hatching of the eggs:

Hatching 1945: On March 5th 4 per cent of the females have hatched, and on April 9th this is the case with 72 per cent. On April 25th 99 per cent have hatched and also to some extent moulted after hatching. On May 23rd 97 per cent of the prawns have moulted after hatching, while 3 per cent still have setae on the pleopods. The presence of setae indicates that the eggs probably have hatched quite recently. On June 13th all females have moulted after hatching.

Hatching 1946: Hatching has possibly commenced by February 21st as on this date we find two individuals out of 23 which have hatched or perhaps lost their roe, while the remainder still carry their eyed eggs. On March 12th 5 per cent of the females have hatched, and on April 15th 78 per cent have hatched and partly moulted. On May 20th we find no females with eggs. On this date 98 per cent of the prawns have moulted after hatching while two per cent still have setae on the pleopods thus indicating that hatching has occurred comparatively recently. On June 13th we find a single individual who has not moulted after spawning, as setae are present.

Hatching 1947: On January 20th the eggs are faintly eyed. On April 8th 45 per cent of the females have hatched their roe. On April 28th 84 per cent of the females have hatched, and 3 per cent have also moulted after hatching.

Hatching 1948: On February 25th the eggs are faintly eyed and obviously not ripe for hatching. A few individuals without eggs but with setae on the pleopods have possibly lost their roe before hatching. On March 18th 3 per cent, and on April 6th 30 per cent of the females have hatched their roe.

From our material it is evident that hatching every year takes place at least from early March till the end of April. The state of some females

furthermore indicates that hatching may start perhaps in February and last till the latter half of May. The hatching in the Oslo Fjord covers in any case a period of at least 8—9 weeks, which is the duration of the hatching period found by HJORT and RUUD in 1934.

The average ovigerous period, taken from the end of spawning till the end of hatching, is about 5 months, i. e. from the middle of December till the middle of May. This corresponds largely with the findings of HJORT and RUUD. However, the termination of both spawning and hatching in 1945—1948 falls on the average about two weeks later than in 1933—1934. Ovigerous prawns have actually been found in our material from October 13th till April 28th, i. e. over a period of 6½ to 7 months. But within one and the same year the period is shorter.

A number of females loose their eggs before they become naturally hatched. Such females can be found in most samples taken during the ovigerous period. From 2 to 6 per cent, or an average of 3,5 per cent of the females apparently lose their eggs some time after spawning. The reason for this loss of eggs in *Pandalus borealis* cannot be stated with certainty. HANS HØGLUND (1942) has ascertained by aquarium experiments that a similar loss of eggs in the prawn *Leander squilla* is due to lack of fertilization of the eggs at the moment of spawning. In *Leander squilla* spawning takes place even if the female has not succeeded in mating. Eggs laid under such conditions do not become attached but fall to the bottom immediately or at the latest after a few hours.

Interesting observations on mating and oviposition of *Pandalus danae* in aquarium have been published by BERKELEY (1931). This deep sea prawn is the most important species near Vancouver on the Pacific, and it is closely related to *Pandalus borealis*. The *Pandalus danae* with mature ovaries moults shortly before spawning, and the eggs are laid usually about 36 hours after the moult. At this moult the pleopods develope the long numerous setae characteristic of ovigerous females. Mating can take place any time within the 36 hours. In moving from the oviducts the eggs pass over a mass of sperms deposited by the male at the bases of the fourth and fifth pair of pereiopods. As the eggs pass this spot the sharply pointed sperms penetrate into the eggs. The whole process of oviposition occupies about half an hour. However, in the artificial surroundings of the experiment none of the females succeeded in fixing the eggs to the pleopods, and they were always shaken off after an hour or two after laying. Ordinarily the eggs after deposition are surrounded by a clear membrane, threads of which attach them to each other and to the pleopods. This membrane was not present in the eggs laid in captivity, and Berkeley is of the opinion that some unfavourable and unexplainable condition prevented the action of the glands which usually secrete the egg cement.

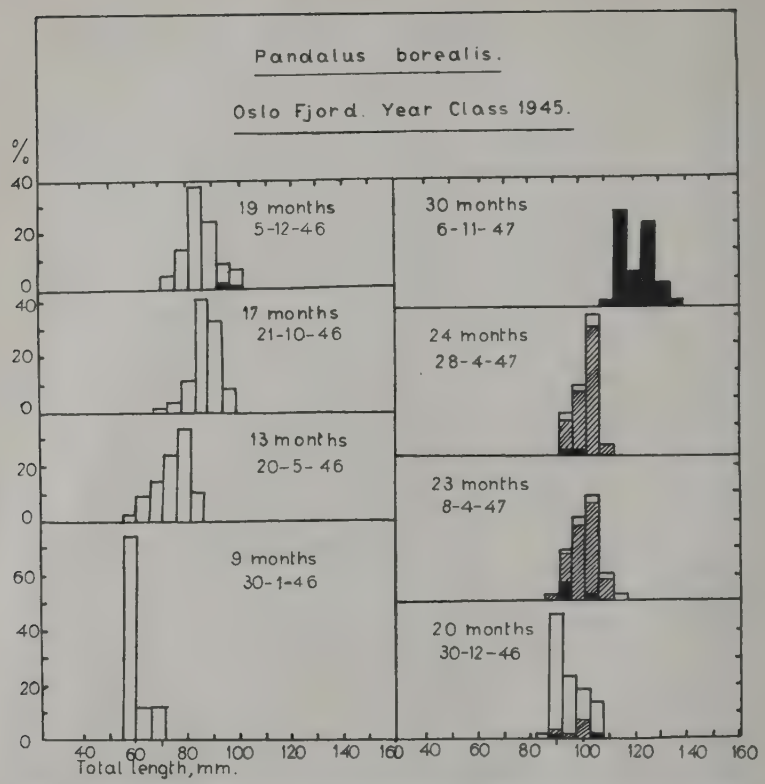

Fig. 9. The Growth and Development of the Year Class 1945 from the Oslo Fjord.

Growth and Sexual Developmnet.

The material collected from the Oslo Fjord enables us to study the growth and development of 4 different year classes of prawns born between 1943 and 1946. The material does not, however, give a complete picture of the growth and development of all these year classes. This is partly due to the composition of the individual samples and partly due to variations in sexual development, growth and numerical strength of the different year classes. For the sake of clarity each year class will in the following be treated independently, according to the complexity of their sexual development.

The Year Class 1945.

The growth and sexual development of the year class born in 1945 are illustrated in fig. 9. In this figure the male prawns are shown as white columns, the transition animals as shaded columns and the ovigerous females as black columns. The details in regard to growth and maturing appear in table III.

Year class 1945.

TABLE III. Oslo Fjord.

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Jan. 30. 1946	9	8	100	60,31		—	—	—	60,31
Febr. 21. »	10	24	100	63,60	—		—	—	63,60
March 12. »	10,5	16	100	64,93	—	—	—	—	64,93
April 15. »	11,5	34	100	71,55	—	—	—	—	71.55
May 20. »	13	46	100	75,15	—	—	—	—	75,15
June 13. »	13,5	187	100	78,28	—	—	—	—	78,28
Oct. 21. »	18	84	100	91,53	—	—	-	—	91,53
Nov. 11. »	18,5	82	98,8	93,17	1,2	106,00	—	—	93,33
Dec. 5. »	19	188	97,9	91,90	—	—	2,1	102,03	92,11
Dec. 30. »	20	45	84,5	94,71	11,0	97,50	4,5	98,05	95,19
Jan. 20. 1947	21	139	56,9	92,38	42,4	97,94	0,7	95,40	94,39
April 8. »	23	53	13,2	105,26	79,3	102,87	7,5	98,05	102,82
April 28. »	24	38	10,5	102,03	84,2	103,67	5,3	98,05	103,19
Oct. 13. »	29,5	33	—	—	100,0	124,29	—	—	124,29
Nov. 6. »	30	28	—	—	—	—	100	122,96	122,96
Nov. 28. »	31	11	—	—	—	—	100	122,85	122,85
Dec. 18. »	31,5	42	—	—	—	—	100	123,01	123,01
Jan. 9. 1948	32	17	—	—	—	—	100	124,07	124,07
Febr. 3. »	33	16	—	—	—	—	100	121,58	121,58
Febr. 25. »	34	8	—	—	—	—	100	123,91	123,91

Our first aquaintance with the year class 1945 is made at the end of January 1946 when the prawns are 9 months old. In the inner Oslo Fjord we may reckon the age from May 1st when hatching of the eggs is mainly over. At an age of one year the members of the year class 1945 measure about 72 mm, and at an age of 18 months the size is 92 mm.

At an age of 1½ years the great majority of the year class are sexually mature males. But among the prawns belonging to this year group we find a few individuals which mature as females and become ovigerous

at this age. We can trace these young female spawners in the samples from late autumn, when they appear as females with ripe ovaries, through the ovigerous period till the eggs hatch in the spring of 1947. The prawns thus becoming ovigerous in their second year are very few, on the average 2,8 per cent of the year class. In regard to size they are larger than the male prawns of the same age (18 months).

The females do not grow in the ovigerous period while the rest of the year class add to their size during the winter and early spring. During the egg-bearing period from December 5th till April 20th the mean size of the young females is 99,06 mm. The size of the sexually mature males when 1½ years of age is about 92 mm.

After the eggs have hatched and the young females have moulted in spring, we are not able any longer to distinguish these early female spawners as a separate group. From fig. 9 it is apparent that it is the largest individuals of the age group which show the tendency to develop into females in the autumn at an age of 1½ years. These young spawners will later on be referred to as the spawning group ♀I.

We may now return to that group of prawns which spawned as males in the autumn when 1½ year old. In December when the prawns are 20 months old, the male group suddenly splits into two fractions. One fraction, 11 per cent, have entered the transition stage, while the rest of the group still shows male characters. In the succeeding months an increasing number of males enter the transition stage with the result that at the end of April 1947 84 per cent of the year class are transition animals. By October all members of the year class have changed into females ready for spawning.

The transition from male into female is performed in 3 stages, termed B, C, and D, which can be sorted out in the material. On January 20th 1947 we find 88 per cent of the transition animals in stage B, in early April 56 per cent have entered stage C, while at the end of April 9 per cent have entered stage D. The transformation into females probably lasts all summer, and by October 10th the whole group appears as females with ripe ovaries. It is the largest individuals of the male group which first enter the transition stages, while the smaller males transform gradually with increasing size during spring and summer.

When the prawn functions as active male 18 months old it has a size of about 92 mm. As spawning female 30 months old it has attained a size of about 123 mm.

The females do not increase in size during the ovigerous period as no moulting can take place. The mean size of the ovigerous females in all samples from November 28th 1947 till February 25th 1948 is 123,01 mm. This is also the size of the prawns upon reaching 3 years of age.

The year class 1945 shows a growth and a sexual development which agree very closely with those found by Hjort and Ruud. Other year-classes, however, show traits which distinguish them from the one described above. This is for instance the case with the year class 1946.

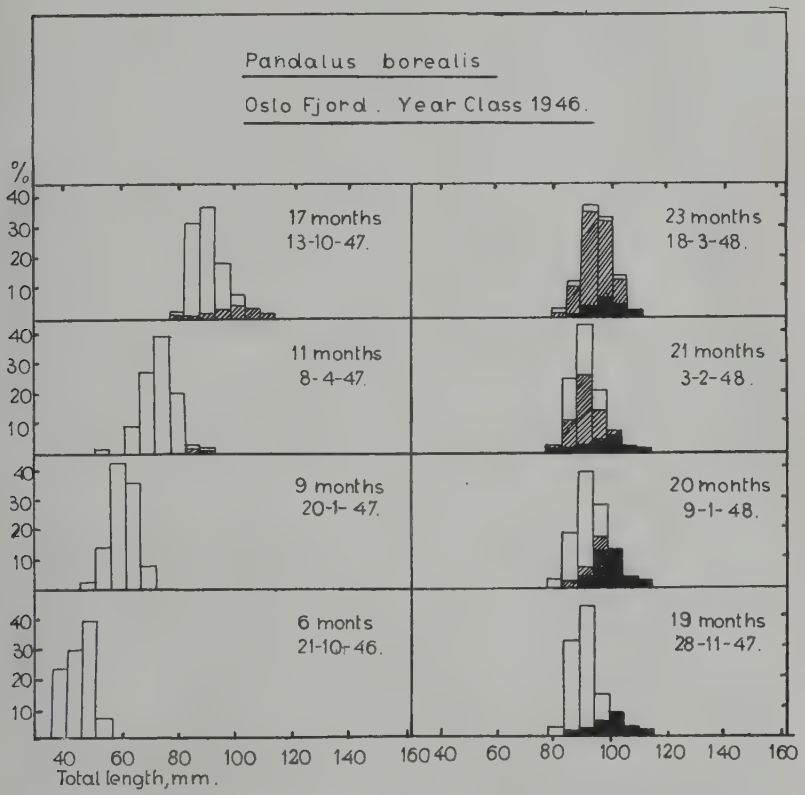

Fig. 10. The Growth and Development of the Year Class 1946 from the Oslo Fjord.

The Year Class 1946.

The youngest individuals belonging to the year class 1946 are found in a sample from October 21st 1946. This sample contains 43 individuals 6 months of age having a mean length of 44 mm. From this starting point we are able to trace the subsequent growth and development as illustrated in fig. 10. The details of the life history are listed in table IV.

Year class 1946.

TABLE IV. Oslo Fjord.

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Oct. 21. 1946	6	43	100	43,99	—	—	—	—	43,99
Nov. 11. »	6,5	15	100	51,57	—	—	—	—	51,57
Dec. 5. »	7	60	100	52,47	—	—	—	—	52,47
Dec. 30. »	8	215	100	58,09	—	—	—	—	58,09
Jan. 20. 1947	9	258	100	60,42	—	—	—	—	60,42
April 8. »	11	419	98,8	72,98	1,2	86,92	—	—	73,14
April 28. »	12	838	99,7	73,99	0,3	88,35	—	—	74,04
Oct. 13. »	17,5	523	89,3	89,31	10,7	100,44	—	—	90,52
Nov. 6. »	18	443	85,5	87,77	—	—	14,5	98,79	89,36
Nov. 28. »	19	450	84,2	88,40	—	—	15,8	99,43	90,15
Dec. 18. »	19,5	379	83,4	89,57	—	—	16,6	101,55	91,53
Jan. 9. 1948	20	278	61,5	89,25	6,8	92,33	31,7	98,53	92,43
Febr. 3. »	21	360	40,2	88,78	43,9	89,78	15,9	98,10	90,68
Febr. 25. »	22	291	8,2	89,20	68,4	90,68	23,4	98,05	92,22
March 18. »	22,5	322	5,9	90,63	79,2	92,22	14,9	96,62	92,80

In April 1947, when the prawns are one year old, we find that a few of them have started to transform into females. By October of the same year we find that about 11 per cent of the year class have changed into females with mature ovaries. In November this female fraction becomes ovigerous, and the young female spawners are found in the ovigerous state all winter. On the average they constitute 18,2 per cent of the year class and their mean size is 98,79 mm.

These early maturing females are thus below the size normally found in fullgrown female prawns. The young females can be traced in the material till March 1948 when the last sample was taken.

During the spawning in autumn of 1947, when the prawn is 1½ years old, we thus find that the year class comprises two spawning groups, one male group with a mean size of about 89 mm containing on an average 81,8 per cent of the individuals, and one female group having a mean length of 99 mm constituting 18,2 per cent of the year class.

The majority of the prawns belonging to the year class 1946 are thus active males in the autumn of 1947. A few months after spawning, at an age of 20 months, the males commence their tranformation into females. As was the case with the year class 1945 the transition does not

occur suddenly and simultaneously in all individuals, but takes place successively as the season advances. Again it is the largest and most fast-growing individuals which apparently have the tendency first to enter the transition stage. In our last sample taken on March 18th 1948 we find that 93 per cent of the male fraction have commenced the transformation. At this date we find that 84 per cent of the transition animals are in the transition stage B, while 15 per cent are in stage C and one per cent in stage D. None of them have as yet attained the external female characters of stage E. It is still 8 months left till spawning begins, and we may safely assume that the individuals which still have male characters in March, will enter the transition stage in the near future, and that the whole year class will be actively spawning females in the autumn of 1948 at an age of 2½ years.

Upon spawning at an age of 18 months the spawning group ♀ I had a mean length of about 99 mm, while the males of the same age measured 89 mm. While egg-bearing these females do not increase in size. As regards the prawns with male characters these show no increase in their mean size from autumn 1947 till spring 1948. The retardation in growth while spawning from October till December is real enough. But after December the members of the male fraction of the year class probably do increase in length in spite of the fact that the computed lengths show stagnation. The explanation is that the largest individuals leave the male group and enter the group of transition animals. Upon loosing their largest members the remaining males must increase in length in order to maintain their usual mean size.

The main difference between the year classes 1945 and 1946 is that in the former 2,6 per cent of the prawns became ovigerous while 1½ years of age, while in the latter 18,2 per cent matured as females at that age.

The Year Class 1943.

The year class 1943 of the deep sea prawn in the inner Oslo Fjord shows a development which is distinctly different from that of both 1945 and 1946.

In our first sample from the Oslo Fjord, taken on May 31st 1944, the year class 1943 is represented by a comparatively large number of individuals, which include prawns with both male and transition characters. The age of the prawns in the first sample is 13 months. The males have a mean size of about 79 mm and the transition animals 86 mm. From this starting point the year class can be traced in the samples taken through 1944 and 1945. The growth and development of the year class 1943 are illustrated in fig. 11, and the details are listed in table V.

Year class 1943.

TABLE V. Oslo Fjord.

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
May 31. 1944	13	415	93,7	79,13	6,3	85,60	—	—	79,55
July 7. »	14	316	93,3	82,95	6,7	90,62	—	—	83,55
Aug. 23. »	16	373	90,9	89,62	9,1	100,70	—	—	90,63
Sept. 13. »	16,5	281	95,0	89,62	5,0	107,91	—	—	90,52
Nov. 27. »	19	437	94,7	89,68	—	—	5,3	100,70	90,26
Dec. 29. »	20	389	95,9	88,72	—	—	4,1	99,06	89,04
Jan. 12. 1945	20,5	450	91,3	89,13	1,4	95,40	7,3	101,50	90,15
Jan. 29. »	21	275	88,4	89,41	8,7	97,63	2,9	102,03	90,52
Febr. 12. »	21,5	305	79,4	91,90	17,0	99,69	3,6	99,74	93,55
March 5. »	22	414	81,5	92,86	15,8	99,31	2,7	99,74	94,08
Apr. 9. »	23	394	84,0	93,39	12,8	103,19	3,2	108,65	95,14
Apr. 25. »	24	332	77,6	93,76	21,8	103,88	0,6	108,65	96,04
May 23. »	25	239	80,0	96,62	19,6	105,21	0,4	111,3	98,37
June 13. »	25,5	305	82,2	98,37	17,8	108,28	—	—	100,12
July 12. »	26,5	234	83,6	100,33	16,4	112,25	—	—	102,24
Aug. 1. »	27	195	84,6	102,13	15,4	115,38	—	—	104,15
Aug. 23. »	28	174	81,5	102,87	18,5	115,28	—	—	105,15
Nov. 15. »	30,5	298	77,0	103,67	—	—	23,0	118,61	107,11
Dec. 10. »	31,5	326	73,0	102,56	0,9	107,75	26,1	121,58	107,59
Jan. 8. 1946	32	265	79,2	103,09	2,3	104,25	18,5	121,26	106,48
Jan. 30. »	33	189	58,2	102,87	13,8	107,43	28,0	124,39	109,55
Febr. 21. »	34	200	41,5	102,93	48,5	106,00	10,0	122,96	106,42

With reference to the figure and table the life history of this year class can be traced as follows: Already in the first sample, taken on May 31st 1944, we find that the year class 1943 has split into two fractions, one with male characters and the other with transition characters. At this date the prawns are about one year old. The two fractions are observed in the subsequent samples. By November 1944 the transition animals have matured into actively spawning females at an age of 18 months. During the period from May till November we find that on the average 6,5 per cent of the year class 1943 mature as females. In regard to size they are larger than the males of the same age. The mean size of the young females (spawning group ♀ I) during the ovigerous period from November till March is 100,59 mm. As they do not grow while egg-bearing this may also be considered the average size reached while spawning in November. At the time of spawning

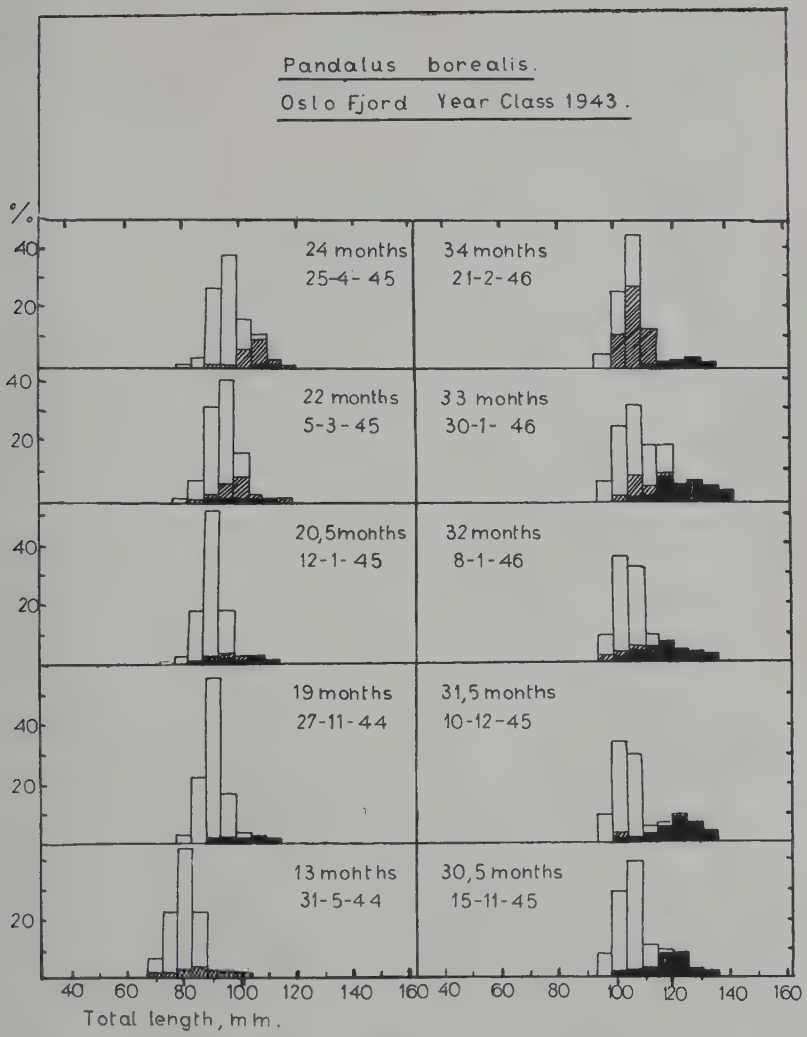

Fig. 11. The Growth and Development of the Year Class 1943 from the Oslo Fjord.

the individuals of the male fraction have reached a mean size of only 89,6 mm.

The egg-bearing young females are found as a separate group in the various samples throughout the winter. Towards the spring of 1945, however, they occur in steadily decreasing numbers. After the eggs have

hatched and the prawns have moulted they increase rapidly in size. From June we cannot trace their further fate.

We may now return to those prawns which were active males in October—November 1944 at an age of 1½ years. These spawning males constitute about 93,5 per cent of the year class. A few months after spawning, in January 1945, a second division of the year class is commenced. The number of individuals entering the transition stage increases during the spring and summer of 1945. In the sample from November we find them as sexually mature females which have become egg-bearing at an age of 2½ years. These ovigerous female are found as a group in the samples till the end of February 1946. On the average they constitute 21,6 per cent of the year class, and their mean size is 121,42 mm, i. e. about 21 mm larger than the ovigerous prawns belonging to spawning group ♀ I.

At the age of 2½ years on an average 78,4 per cent of the year class 1943 spawn as males for the second time in life. At that age the males have attained a mean size of only 103 mm, i. e. 18 mm below the size of the animals which have matured as females at the same age.

When comparing the growth of the two fractions from the age of 1½ to 2½ years, it is apparant that the individuals destined to become females have a much faster rate of growth. During one year of life, between the age of 1½ and 2½ years, the males increase in size from about 90 to 103 mm, i. e. an increment of 13 mm, while the females in the same period increase in size from 90 to 121 mm, i. e. an increment of 31 mm. As clearly demonstrated in the figure and in the table, it is again primarily the largest individuals of a group of male prawns which have the tendency first to change into females. After entering the transition stage the female fraction has the faster rate of growth.

We may now return to those of the fraction which were active males for the second time in November 1945. About a month after spawning we find that a third division of the year class has commenced. During the first months of 1946 a steadily increasing number of the males enter the transition stage. At the end of February 1946 about 54 per cent of the individuals which acted as males last autumn have commenced the changing of sex. We cannot trace with absolute certainty the further development, but as far as can be ascertained from the material at hand, the majority, or probably the whole of the male fraction, will change their sex during the spring and summer. In the autumn they will spawn as females and become ovigerous for the first time in life at an age of 3½ years (spawning group ♀ III). At that age they will presumably have reached a size of about 120 mm, i. e. the same size as reached by spawning group ♀ II one year earlier.

After February 1946 the numerical strength of the year class 1943 decreases rapidly and at the same time it is intermixed with other year classes to such an extent that an accurate segregation of this particular year class with its branches of males, transition animals and females, is not feasible.

The Year Class 1944.

The year class 1944 of the deep sea prawn in the inner Oslo Fjord has apparently been extremely poor. Ordinarily this year class would have entered the hauls during the first winter months of 1945 and dominated the catches in the subsequent summer. But this is not the case. At the end of May 1945 the year class 1944 contributes only 4 per cent to the catch, and the same percentage is found in August of the same year. During the first months of 1946, when approaching the age of two years, they are somewhat more numerous. At the same time they become intermixed with the far stronger year class 1945, and it becomes increasingly difficult to segregate the year class 1944 as a separate group. The details in regard to rate of growth and sexual development during the first 22 months of life are listed in table VI.

Year class 1944.

TABLE VI. Oslo Fjord

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Jan. 12. 1945	8,5	7	100	56,82	—	—	—	—	56,82
Jan. 29. »	9	6	100	57,40	—	—	—	—	57,40
Febr. 12. »	9,5	5	100	58,30	—	—	—	—	58,30
March 5. »	10	23	87,0	59,89	13,0	61,85	—	—	60,16
April 9. »	11	14	92,0	68,90	8,0	63,60	—	—	68,53
April 25. »	12	22	95,5	69,91	4,5	79,50	—	—	70,33
May 23. »	13	12	100	76,85	—	—	—	—	76,85
June 13. »	13,5	9	89,0	78,18	11,0	90,10	—	—	79,50
July 12. »	14,5	9	100	78,92	—	—	—	—	78,92
Aug. 1. »	15	8	100	84,16	—	—	—	—	84,16
Aug. 23. »	16	12	100	84,38	—	—	—	—	84,38
Nov. 15. »	18,5	70	97,1	88,56	—	—	2,9	90,10	88,72
Dec. 10. »	19,5	52	100	88,67	—	—	—	—	88,67
Jan. 8. 1946	20	53	100	88,99	—	—	—	—	88,99
Jan. 30. »	21	46	97,5	88,51	—	—	2,5	90,10	88,56
Febr. 21. »	22	38	83,3	88,14	16,7	91,16	—	—	88,62

In the individual samples the number of prawns belonging to the year class 1944 is very small, and this fact makes it difficult to outline the actual development. However, the figures indicate that when the prawns are one year old a certain amount of desintegration occurs in the year class. When the prawns are 1½ years of age 3 to 5 per cent of the year class mature as females and become ovigerous in the autumn. The size of these females (spawning group ♀ I) is about 90 mm, while the rest of the year class which function as males, have a size of about 88 mm. Neither the males nor the females show any growth from the moment of spawning in the autumn of 1945 till February 1946. At the latter date a second division of the year class has commenced. We find that 17 per cent of the males have entered the transition stage, while the rest still remain males. Whether the whole group will mature as females when 2½ years of age, or a part of it still will be males at that age, cannot be ascertained from the material.

On the Variation in Growth and Sexual Development.

The description of the growth and the sexual development of the various year classes of prawns in the inner Oslo Fjord given in the preceding pages, leaves the impression that the rate of growth and the cycle of sexual development are not constant from one year to another in this locality. Presumeably annual changes in the environment effect the growth and development of the prawn stock.

For the sake of clarity the results in regard to growth and development of the different year classes can be summarized as follows:

The year class 1943: When 1½ years old 93,5 per cent of the individuals are active males of a mean size of 89,6 mm. Simultaneously 6,5 per cent are ovigerous females measuring 100,59 mm (spawning group ♀ I). When 2½ years of age 78,4 per cent of the year class spawn as males for the second time, having attained a size of 103 mm, while 21,6 per cent mature as females, at a mean size of 121,42 mm (spawning group ♀ II). When 3½ years old probably the rest will change into females (spawning group ♀ III).

The year class 1944: When 1½ years of age 3—5 per cent of the prawns spawn as females at a size of 90 mm (spawning group ♀ I), while the rest of the year class function as males. The size of the latter is 88 mm. The year class is too poorly represented to give definite information of the further life history.

The year class 1945: When 1½ years old 2,6 per cent are mature females having reached a size of 98 mm (spawning group ♀ I). At the same age the rest function as males, having attained a size of 92 mm.

When 2½ years of age all prawns have changed into females measuring averagely 123 mm (spawning group ♀ II).

The year class 1946: When 1½ years of age 18,2 per cent are spawning females at a size of 98,79 mm (spawning group ♀ I), while the rest at the same age function as males. The latter have attained a size of 89 mm. When 2½ years of age presumeably all have changed into females and become ovigerous.

According to HJORT and RUUD, who derived their results from a study of the year class 1933, all or most of the prawns of this year class matured as males at an age of 1½ years and a size of 93 mm. When 2½ years old, all, or most, of the prawns were ovigerous females having attained a size of 120 mm.

The most notable fact shown by the present material is that it seems to be a general rule that a varying number of prawns mature as females at an age of 1½ years. In the different year classes between 2,6 and 18,2 per cent of the prawns mature as females at such an early age. Upon reaching the age of 2½ years the general rule seems to be that all, or most, prawns mature as females. A distinct exception from this rule is the year class 1943 of which only 21,6 per cent became ovigerous at an age of 2½ years while the rest of the year class functioned as males for the second time. The majority of the prawns did not mature as females till they were 3½ years old.

The extreme variations in sexual development found in the inner Oslo Fjord are most probably caused by varying living conditions. We have, however, no hydrographic data on which we with certainty can base an assumption as to the causes. As mentioned earlier, the inner Oslo Fjord is cut off from the outer basin by a shallow threshold. The salinity, temperature and oxygen content of the water near the bottom are to a large extent influenced by the surface currents and by the prevailing winds. Unusual conditions existed for instance in the autumn of 1945 when the innermost part of the Oslo Fjord (the Bonne Fjord) was "dead" on account of the presence of hydrogen sulphide in the water masses near the bottom. The layer of stagnant water this year reached an unusual thickness. The fishermen assert that no marine life existed deeper than 15—20 fathoms.

In the preceding year, in 1944, the fishery in the Oslo Fjord had not given satisfactory results. The fishermen were of the opinion that the set-back in the fishery was due to the great amount of fuel oil which had been spilled in the fjord. From a tanker grounded near the entrance heavy crude oil poured out, spread over the fjord and sank to the bottom, covering even the deepest parts. The presence of oil along the bottom was noticeably detrimental to the prawn fishery.

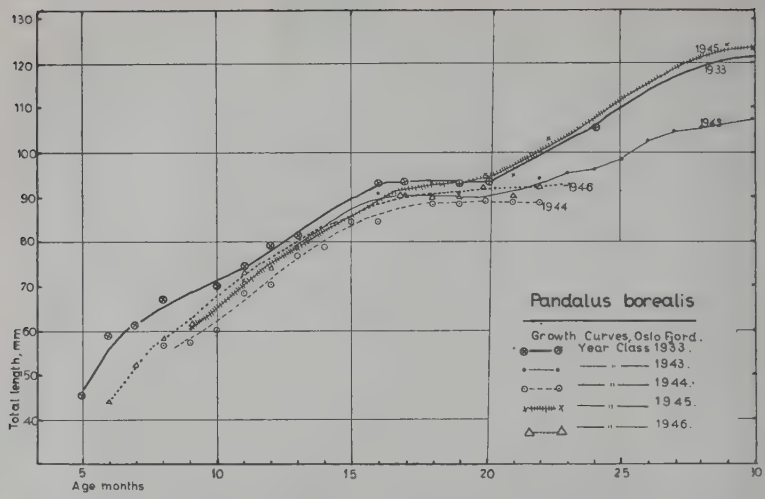

Fig. 12. Growth Curves of the Various Year Classes of Prawns in the Oslo Fjord.

It is not inconceivable that the layer of oil along the bottom, and likewise the possible presence of hydrogen sulphide in the deeper parts, may have influenced the feeding conditions and thus also the growth and development of the prawns. In the fall of 1945 the year class 1943 is 2½ years of age and should normally be expected to consist of mature females. Instead most of the prawns retain their male characters without change of sex. The presence of hydrogen sulphide along the bottom in the inner part of the fjord indicates that exchange of the water has not taken place for a long time. This fact together with the spreading of oil along the bottom may perhaps account for the slow growth and maturing of the 1943 year class and likewise explain the extreme poorness of the year class 1944.

As mentioned before the various year classes of prawns in the Oslo Fjord have been found to differ in regard to rate of growth. Fig. 12 illustrates the growth curves for the various year classes, and in table VII are listed the mean lengths of the year classes found at varying age. Variations in sexual development are here not taken into account.

The variation in growth is observed quite early in the life of the prawn. For instance, during the first 17 months the year class 1933 shows a faster rate of growth than any of the other year classes.

TABLE VII. Oslo Fjord

Growth Rates of Different Year Classes.

Appr. age months	Year class				
	1943 mm	1944 mm	1945 mm	1946 mm	1933* mm
5	—	—	—	—	44,67
6	—	—	—	43,99	58,94
7	—	—	—	52,47	61,55
8	—	56,82	—	58,09	67,04
9	—	57,40	60,31	60,42	—
10	—	60,16	64,93	—	70,24
11	—	68,53	71,55	73,14	74,37
12	—	70,32	75,15	74,04	79,12
13	79,55	76,85	78,28	—	80,97
14	83,48	78,92	—	—	—
15	—	84,16	—	—	—
16	90,63	84,38	—	—	93,25
17	90,52	—	91,53	90,52	93,05
18	—	88,72	93,33	89,36	—
19	90,26	88,67	92,11	90,15	92,47
20	89,04	88,99	95,19	92,43	93,27
21	90,52	88,56	94,39	90,68	—
22	94,08	88,62	—	92,22	—
23	95,14	—	102,82	92,80	—
24	96,04	—	103,19	—	106,77
25	98,37	—	—	—	—
26	102,24	—	—	—	—
27	104,15	—	—	—	—
28	105,15	—	—	—	—
29	—	—	124,29	—	120,92
30	107,11	—	122,96	—	—

* From HJORT and RUUD.

The differences become more pronounced and variegated when the prawns grow older. At an age of 24 months the prawns of the 1933 year class have a mean length of 107 mm, the 1943 class 96 mm and the 1945 class 103 mm. At an age of 2½ years the same year classes measure respectively 121, 107 and 123 mm.

As regards the comparison of the present material with that of the 1933 year class collected by HJORT and RUUD, the possibility cannot be excluded that the variations to some degree may be due to the different methods used in meassuring the prawns.

The variations in rate of growth observed in the different year classes must be viewed with due regard to the changing sexual development in each year class. The division of a year class into different size groups

and the corresponding ratio of small sized males and large females at the different seasons have a great influence on the calculated mean length of the whole year class.

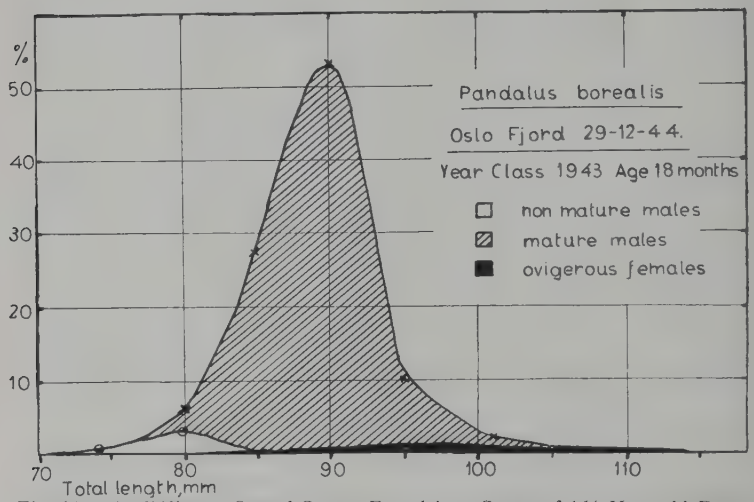

Fig. 13. The Different Sexual Stages Found in a Group of 1½ Year old Prawns in the Oslo Fjord.

On the Variation in Protandry.

As mentioned above, a group of prawn may at a certain point in life split in such a way that the larger individuals become females while the smaller ones remain males. This division within a year group can go still further. In a sample from December 29th 1944 all males of the year group 1943 were examined as to the ripeness of the testes. The result of this examination is shown in fig. 13.

Some of the smallest individuals of the 1½ year old prawns (3,3 %) contained no sexual products in the testes and could not spawn as males that year. The majority of the age group were active males, while a few of the largest individuals of the age group (4,1 %) had transformed into females. Thus a double division within the age group had taken place. A similar examination of the year class 1944 caught on November 15th 1945 (1½ years old) proved that in this case all males were sexually mature even if small of size. The non-maturing of the small males of the year class 1943 is probably related to the gene-

ral slow growth and maturing of this particular year class compared with the others.

In the material we also find some individuals obviously born with external female characters. , In 12 samples collected between March 5th 1945 and April 15th 1946 the O-group and I-group were closely examined as to the type of external sexual characters. In 3 samples from March and April 1945 altogether 5 prawns were found which showed no trace of having gone through the usual male stage. The endopodite of the first pair of pleopods was of a long and slender shape, typical of older females. These young prawns belonged to the O-group and measured 58—79 mm, on an average 66 mm.

JÄGERSTEN(1936) divides the female prawns into three categories, namely primary females, secondary females and hermaphroditic females. Among others he suggests the explanation that all individuals are hermaphroditic and have both male and female potentialities. If the male potentiality is repressed before the external male characters are formed, the individual is a "primary female" which becomes ovigerous when 1½ years old. In others the male potentialities are repressed after the external male characters have appeared, but nevertheless so early that they become ovigerous when 1½ years of age. These latter are the "secondary females". JÄGERSTEN found in the Gullmar Fjord (Sweden) that of the females about 5 % were 1½ years old, and among these the primary females were in majority.

In the Oslo Fjord the number of early female spawners seems to vary from year to year, but in any case the individuals belonging to the category of primary females are rather an exception here, while the secondary females are more preponderant among the early female spawners. As in the Gullmar Fjord, the majority of large prawns here are hermaphroditic females in which the potentialities are repressed only after the individual has functioned as a male for one season.

HJORT and RUUD (1938) regard all categories of sexually mature individuals as the result of a labile equilibrium between male and female potentialities, the age of reaching female maturity being dependent upon the stage in life at which the male potentiality is repressed. In my opinion this may be considered a general statement which holds true for all prawn populations, with the modification that the local rate of growth and yearly changes in the environment to a great extent determine the time at which the male potentiality is to be repressed. This effect is more pronounced in other localities than in the Oslo Fjord.

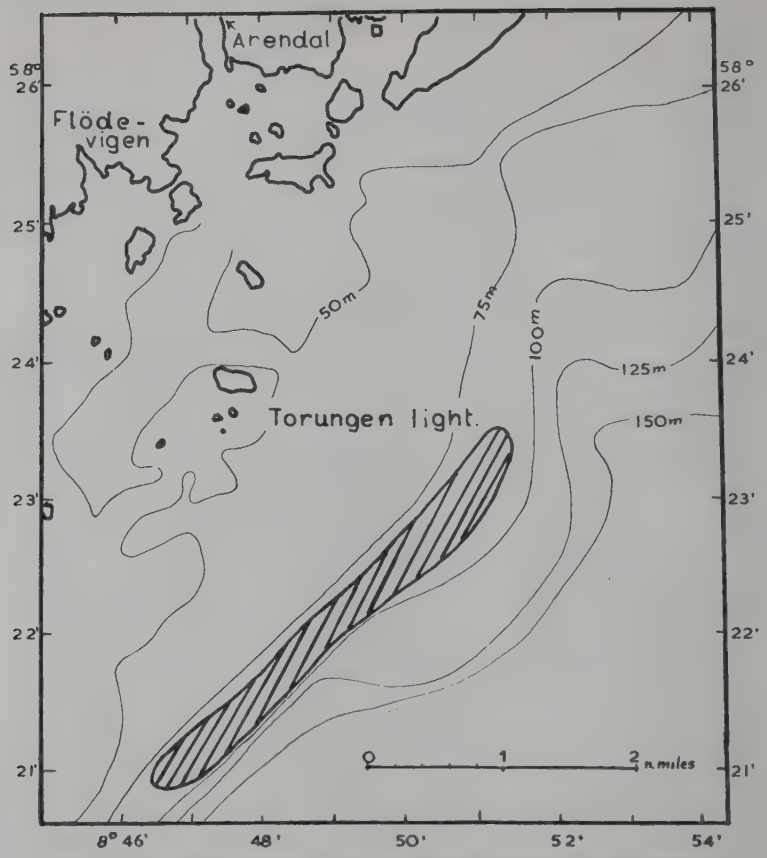

Fig. 14. Chart Showing the Situation of the Torungen Prawn Ground.

The Life History of the Deep Sea Prawn on the Torungen Ground (Skagerak Area).

The Prawn Ground.

The Torungen prawn ground is situated about 2—3 miles off the Torungen Light in the vicinity of Arendal. The general fishing depths are 80—100 meters. The trawl ground is being fished all the year round if weather conditions permit, and then mostly by vessels from Arendal. A chart of the Torungen prawn ground is shown in fig. 14.

The hydrography of this area has been studied by ALF DANNEVIG (1940). His survey of the hydrographic conditions covers the year 1937. According to the observations of DANNEVIG the temperature at 80—100 meters depth is in June 6—7° C. Later in summer the temperature increases to 8—10° C. In November the winter conditions commence and the temperatures in the various layers decrease gradually. In February—March the temperature is uniformly about 6° C, in April slightly lower.

The salinity of the sea water at 80—100 meters is usually about 34,5 ‰, i. e. water of North Sea origin. In July we find water of Atlantic origin (35 ‰ or more) at a depth of 100 meters, in September at 70—100 meters, and in November at about 50 meters. This conforms with the general consensus of opinion that on the Skagerak Coast the great influx of Atlantic water occurs in late autumn. Thus, on the prawn field off Torungen the water has thoughout the year a higher salinity than what is found in the Oslo Fjord. In the latter locality it varied between 33,15 and 33,60 ‰ during the year.

The oxygen measurements indicate that the sea-water is well ventilated to a depth of at least 300 meters, and thus also on the prawn ground. The hydrographic situation may vary greatly in the details from day to day, and the meteorological character of the year may give rise to great fluctuations, not only in the surface layers but also in the bottom water. For instance during the severe cold winter of 1924 the temperature in deeper layers dropped to 4° C while it is ordinarily about 6° C.

Extraordinary hydrographic conditions existed in this area during winter and spring of 1947. The trawling for prawns was during the first part of the year completely hindered by heavy sea ice. Although the prawn fields were thus not fished for several months, the catches remained poor far into the summer. Hydrographic observations have been taken by DANNEVIG in 1946—1947 at a station 5 miles SSE of Torungen Light. At a depth of 150 meters he found the temperatures and salinities listed in table VIII.

TABLE VIII. TORUNGEN

Date	Temp. °C	S o/oo
Oct. 17. 1946	7,43	35,12
March 25. 1947	6,64	,01
April 10. »	2,99	34,70
June 1. »	4,14	,88
Oct. 27. »	7,20	,81

Jens Eggvin (1948) has studied the hydrographic conditions in this period. He remarks that the deeper strata in parts of the Norwegian Channel could be 2,5° C colder in the summer of 1947 compared with the summer of 1946. The reason for these exceptional conditions was that during the severe winter of 1947 cold water masses were formed in the southern North Sea. The ice cold water reached from surface to bottom, and the trawlers could get fish killed by the frost in their catches. The masses of cold water penetrated northward to the Norwegian Coast with the result that the deep sea fishery here became very poor, and thus also affected the prawn fishery.

The Material.

Samples of deep sea prawns from the Torungen prawn ground have been collected by Mr. Samuel Sand, a prawn fisherman from Arendal. During his ordinary commercial trawling he has at intervals taken samples from this locality. The work of collecting samples was carried out between August 1945 and March 1947. During the last part of the period collection was also carried out with a fin-meshed covering over the ordinary codend. Mr. Sand sent the samples to the Institute for Marine Research in Bergen where they were handled in the usual way.

From the Torungen ground we have at our disposal 20 samples of prawns containing a total of 9055 individuals. The size of each sample and the date of capture are listed in table IX.

Thanks to Mr. Sand's interest in the work, samples were collected continuously from the prawn ground during the whole of this period without any serious break-off. At the laboratory in Bergen the growth and development of the prawn were examined along the same lines as discussed in earlier shapters.

Spawning and Hatching.

The material has been collected over such a long period that it covers two spawning seasons. The spawning in 1945 took place as follows:

In a sample from September 12th all females as well as 6 transition animals in the stages C and D had fully developed ovaries. One individual had undertaken the last moulting before spawning and had aquired the characteristic setae on the pleopods. On October 12th 46 per cent of the females were ovigerous, and on November 5th 98 % of the females were found in this condition.

TABLE IX. Torungen

Date	Number of prawns in	
	Ordinary trawl	Fine-meshed net
Aug. 16. 1945	288	—
Sept. 12. »	553	—
Oct. 12. »	362	—
Nov. 5. »	293	—
Nov. 27. »	389	—
Dec. 21. »	305	—
Jan. 8. 1946	312	—
Febr. 12. »	221	—
March 7. »	215	—
March 28. »	552	—
April 26. »	471	—
June 2. »	521	—
July 23. »	597	—
Aug. 16. »	556	—
Sept. 10. »	255	—
Oct. 8. »	443	161
Nov. 14. »	498	188
Dec. 13. »	399	420
Jan. 20. 1947	377	389
March 15. »	214	76
	7821	1234

In 1946 the development was almost identical. On September 10th all females had maturing ovaries. On October 8th about 8 per cent of the femlaes were ovigerous.

We may assume that the main spawning on the Torungen ground generally takes place between October 1st and November 15th, i. e. a spawning period of 1½ months.

The prawns carry their eggs all winter till hatching starts in early spring. During the spring of 1946 the conditions with regard to hatching were as follows:

On February 12th we find a few individuals without eggs but with setae on the pleopods. These are probably prawns which have lost their eggs at an early stage. In the sample from March 7th none of the ovigerous females have cast their eggs. Three weeks later, on March 28th we find that the eggs have hatched in 91 per cent of the females. On April 26th the eggs of all the females have hatched, and 67 per cent of them have also moulted after hatching, while the rest still have setae on the pleopods.

From the spring of 1947 we have only one sample, dated March 15th. In this sample the eggs have hatched in 69 per cent of the females, while

the remaining are still ovigerous. Presumeably the hatching is mainly limited to the period between March 1st and April 15th, a period of 1½ months.

In comparison with the conditions found in the Oslo Fjord both spawning and hatching among the prawns from the Torungen ground are more concentrated in time and take place a little earlier in the year. The material at hand allows a comparison between the ovigerous periods in both these localities within the same year.

During the spawning season of 1945 a sample from the Oslo Fjord, taken on November 15th, contains 55 per cent ovigerous females; and on December 10th 97 per cent of the females have spawned. During the same spawning period (1945) the material from the Torungen ground contains 46 per cent ovigerous females already by October 12th, while 98 per cent of the females have spawned by November 5th.

The prawns spawning in the autumn of 1945 hatch the brood in the spring of 1946. In the Oslo Fjord we find that 78 per cent of the females have hatched their roe by April 15th. On the Torungen ground, however, 91 per cent of the females have hatched their eggs already by March 28th.

Taking the time from the end of spawning till the end of hatching as the ovigerous period, this covers on the Torungen ground about 5 months, i.e. from the middle of November till the middle of April. The average ovigerous period in the Oslo Fjord was found to be of the same duration, but falls between the middle of December and the middle of May. Thus both spawning and hatching take place about a month later in the Oslo Fjord. It is, however, quite possible that the dates of spawning and hatching as found on the Torungen ground in 1945 and 1946 may be subject to variations in other years, due for instance to varying hydrographic conditions.

Age and Rate of Growth.

The material collected from the Torungen ground contains at least 4 year classes of prawns, each of which contributes its part towards the reconstruction of the life history. As the material has been collected over a period of 18 months only, we are not able to follow the complete life cycle of a single year class. However, by combining the various year classes we are able to obtain a fairly complete picture of the general rate of growth and the sexual development. As each year class shows some variation in growth and development they will be treated separately. In estimating their age April 15th is regarded as the birth day in this locality.

The Year Class 1946.

The year class 1946 contains the youngest and smallest prawns in the material. They are mainly caught in the fine-meshed covering of the prawn trawl employed during collection of the last 5 samples. The year class 1946 enters the catches 6 months old, when the prawns have reached a size of about 47 mm. The subsequent growth of these small prawns is shown in table X.

Year class 1946.

TABLE X. Torungen

Date	No. of prawns	Age months	Mean size mm
Oct. 8. 1946	34	6	46,48
Nov. 14. »	292	7	51,20
Des. 13. »	358	8	52,31
Jan. 1. 1947	421	9	56,60
March15. »	32	11	65,24

None of these prawns shows any transition or female characters indicating that they would mature as females at an early age.

The Year Class 1945.

The first individuals belonging to the prawns born in the spring of 1945 are captured in the trawl in the autumn of the same year when they have reached an age of approximately 6½ months and a size of 52 mm. The subsequent growth and development of this year class are shown in table XI.

When the prawns approach an age of 18 months in the autumn of 1946 we find a very small number of them in the transition stage or as maturing females. These young female spawners constitute only 0,7—3,5 per cent of the year class. As will be seen from the table these individuals are larger than the males of the same age.

At an age of 18 months the majority of the prawns are active males. A short while after mating this male fraction begins to enter the transition stage. A small number of transition animals are found on December 13th 1946, but already a month later the number has increased considerably. By March 15th, when the prawns are 23 months old, 53 per cent of the year class have entered the transition stage. As the collec-

Year class 1945.

TABLE XI. Torungen

Date	Age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	size	% mm	%	size mm	
Nov. 5. 1945....	6,5	13	100	52,21	—	—	—	—	52,21
Nov. 27. »	7,5	19	100	57,77	—	—	—	—	57,77
Des.. 21. »	8	32	100	58,14	—	—	—	—	58,14
Jan. 8. 1946....	9	74	100	60,10	—	—	—	—	60,10
Febr 12. »	10	10	100	61,48	—	—	—	—	61,48
March 7. »	10,5	25	100	61,69	—	—	—	—	61,69
March28. »	11,5	296	100	62,49	—	—	—	—	62,49
April 26. »	12,5	143	100	70,17	—	—	—	—	70,17
June 2. »	13,5	258	100	75,15	—	—	—	—	75,15
July 23. »	15,5	455	100	82,52	—	—	—	—	82,52
Aug. 16. »	16	414	99,3	85,49	0,7	91,85	—	—	85,52
Sept. 10. »	17	196	100	84,16	—	—	—	—	84,16
Oct. 8. »	18	454	98,9	87,93	1,1	90,10	—	—	87,98
Nov. 14. »	19	368	98,1	88,09	—	—	1,9	93,12	88,19
Des. 13. »	20	337	97,9	86,55	1,2	94,80	0,9	90,10	86,71
Jan. 20. 1947....	21	215	86	87,45	13,1	92,96	0,9	95,40	88,03
March15. »	23	85	43,5	87,82	53	93,77	3,5	97,15	91,43

tion of prawn samples was concluded at this stage, we are not able to ascertain how many become active females when 30 months old. Presumeably quite a few of the prawns may retain their male characters also at that age, thus spawning as males for a second time when 2½ year old. Such a development is better illustrated by the year class 1944.

The Year Class 1944.

The rate of growth and the sexual development of the year class 1944 can be traced from a point when the prawn is 16 months old till it is 35 months old. The details of the life history are shown in table XII.

The sexual development of the young prawn of this year class is very similar to that found among the prawns born in 1945. When 18 months old the prawns of the 1944-class have reached an approximate size of 92 mm, and the great majority of them are at this age active males. Only a few individuals (1,0—3,6 %) mature as females. These are found in the ovigerous stage in the subsequent samples.

The change of sex in the males starts a few months after spawning. In December 1945 when the prawns are 20 months old, 7,5 per cent of the males have entered the transition stage. The number steadily increases during the subsequent period. By the next spawning time in October 1946, when the prawns are 30 months old, between 70 and 80 per cent of the year class are mature females, while 20—30 per cent are active males for the second time. The size of the 2½ year old females is about 119 mm, while the males have only reached a size of approximately 105 mm.

Year Class 1944.

TABLE XII. Torungen

Date	Age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Aug. 16. 1945....	16	58	100	90,37	—	—	—	—	90,37
Sept. 12. »	17	393	100	89,78	—	—	—	—	89,78
Okt. 12. »	18	139	100	92,59	—	—	—	—	92,59
Nov. 5. »	18,5	100	100	91,53	—	—	—	—	91,53
Nov. 27. »	19,5	169	100	93,76	—	—	—	—	93,76
Des. 21. »	20	120	92,5	92,54	7,5	96,57	—	—	92,86
Jan. 1. 1946....	21	95	69,5	94,55	29,5	99,38	1,0	90,10	95,72
Febr. 12. »	22	61	47,5	92,27	52,5	100,22	—	—	96,46
March 7. »	22,5	55	43,7	93,17	52,7	99,43	3,6	100,70	96,73
March 28. »	23,5	139	49,6	94,18	46,8	100,28	3,6	96,46	97,10
April 26. »	24,5	237	39,7	96,67	60,3	106,16	—	—	102,40
June 2. »	25,5	222	38,8	98,63	61,2	110,35	—	—	105,79
July 23, »	27,5	131	43,5	102,56	56,5	116,18	—	—	109,45
Aug. 16. »	28	122	46,4	105,47	53,6	115,06	—	—	110,56
Sept. 10. »	29	59	32,2	105,47	67,8	117,40	—	—	113,53
Oct. 8. »	30	140	22,2	107,01	77,8	117,98	—	—	115,54
Nov. 14. »	31	101	23,7	105,36	—	—	76,3	118,93	115,70
Des. 13. »	32	113	23,0	106,80	2,7	106,00	74,3	120,79	117,18
Jan. 20. 1947....	33	115	5,2	106,00	3,5	106,00	91,3	121,21	119,89
March 15. »	35	150	—	—	2,0	113,05	98,0	123,49	123,28

Having functioned as males for the second time the last males of the year class start changing their sex too. When 35 months of age the last members have entered the transition stage. When reaching the next spawning period at 42 months of age the year class 1944 apparently contains no males any longer.

The Year Class 1943.

In the Torungen material the year class 1943 is about 28 months old when encountered in the first sample taken in August 1945. The details of the life history are listed in table XIII.

Year Class 1943.

TABLE XIII. Torungen

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Aug. 16. 1945....	28	166	48,9	107,43	51,2	123,60	—	—	115,70
Sept. 12. »	29	127	59,0	107,22	41,0	118,61	—	—	111,88
Oct. 12. »	30	168	54,8	108,17	45,2	124,07	—	—	115,38
Nov. 5. »	30,5	126	37,3	106,80	—	—	62,7	122,91	116,92
Nov. 27. »	31,5	173	71,6	108,17	—	—	28,4	124,39	112,78
Des. 21. »	32	105	32,4	107,11	19,0	106,0	48,6	126,14	116,12
Jan. 8. 1946....	33	82	15,8	106,42	24,4	111,83	59,8	123,76	118,08
Febr 12. »	34	50	8,0	106,00	28,0	112,84	64,0	123,91	118,83
March 7. »	34,5	52	1,9	111,30	17,3	114,27	80,8	124,02	122,11
March 28. »	35,5	87	—	—	13,8	115,28	86,2	125,93	124,44
April 26. »	36,5	61	—	—	19,7	121,48	80,3	128,74	127,31
June 2. »	37,5	36	—	—	19,4	127,20	80,6	131,23	130,43
July 23. »	39,5	10	—	—	—	—	100	139,39	139,39
Aug. 16. »	40	18	—	—	—	—	100	128,10	128,10
Nov. 14. »	43	3	—	—	—	—	100	143,10	143,10
Des. 13. »	44	11	—	—	—	—	100	145,96	145,96
Jan. 20. 1947....	45	14	—	—	—	—	100	145,01	145,01
March 15. »	47	23	—	—	—	—	100	145,64	145,64

At an age of 30 months the prawns have reached a mean size of about 115 mm. At this age only between 40 and 50 per cent of the prawns have passed through the transition stage and become ovigerous females. The female fraction has at this point a size somewhat above 120 mm. After the hatching of the eggs the following spring they grow rapidly to a size of about 130 mm.

At an age of about 30 months the rest of the year class (50—60 %) are acting as males, probably for the second time in life, after having reached a mean size of about 108 mm. During the following winter the male fraction gradually passes into the transition stages. By the end of March, when 35 months of age, no male prawns are left. By this time the year class is composed of large berried females and smaller

transition animals. During the summer of 1946 the whole year class mature as females. When 3½ years of age all prawns are large and ovigerous and have apparently reached a size of approximately 140—145 mm. However, after 37 months of life the year class 1943 has become so reduced in the catches that its further fate can be traced with only a small degree of certainty.

The Year Class 1942.

When encountered in the material for the first time in August 1945 the year class 1942 is about 40 months old, and it is composed of large females having been ovigerous at least for one season. In the first sample, from August 16th 1945, we are able to distinguish these old female prawns by their size and the shape of the endopodite of the first pair of pleopods. The large females having spawned before, carry a long and slender endopodite, while younger females which have just finished their transition (stage E) have endopodites of a more blunt or rounded shape. In later samples, when the females approache the ovigerous stage, this means of distinguishing the old and young spawners cannot be used. They must then be separated by their size distribution only, a procedure which gives room for errors.

However, the computed mean lengths for the year class 1942, as listed in table XIV, should give an adequate picture of the growth history of these old prawns.

Year class 1942.

TABLE XIV. Torungen

Date	No. of prawns	Age months	Mean size mm
Aug. 16.1945	64	40	136,95
Sept. 12. »	33	41	134,94
Oct. 12. »	55	42	138,86
Nov. 5. »	54	42,5	140,77
Nov. 27. »	28	43,5	139,13
Des. 21. »	48	44	139,34
Jan. 8.1946	61	45	141,09
Febr. 12. »	100	46	142,15
March 7. »	83	46,5	140,82
March 28. »	30	47,5	146,12
April 26. »	30	48,5	146,12
June 2. »	5	49,5	149,46

In discussing the year class 1943 it was stated that after 37 months that year class was so reduced in the catches that it could not be traced with certainty any further. As regards the year class 1942 this is more easily separated and can be traced till an age of 4 years. The latter year class has perhaps been very rich from the start, or taxation through fishing has been less than usual. It is not improbable that both factors may account for the larger number of prawns reaching such an old age. Prawn trawling in the Torungen area was very restricted during the war, and fishery on a larger scale did not start again till the summer of 1945. By that time the year class 1942 would be more than 3 years old without having been subject to any heavy taxation by fishery. Thus a comparatively large number of old prawns could be expected when the fishery started after the war.

Upon reaching an age of 42 months the prawns have a mean size of about 140 mm. At that age the large prawns become ovigerous the second time in life. The prawns do not show any growth during the ovigerous season, but the growth starts again after the eggs have hatched and the prawns moulted in the spring of 1946. When 50 months old the prawns have reached a size of approximately 150 mm.

At this old age the year class 1942 has become so reduced in number that it cannot be traced any further. Presumeably the maximum age reached by the prawn in the Torungen area is about 4½ years.

Summary of Life History.

The mean growth curves of the individual year classes from the Torungen ground are shown in fig. 15.

As will be seen from the figure the 1945 year class shows a faster rate of growth than the 1946 year-class during the first 10 months of life. This discrepancy may, however, be due to the difference in the method of collecting the samples. The small prawns of the 1946 year class were caught in a fine-meshed net covering the cod end proper. Of the 1945 year class many of the smallest prawns have escaped through the meshes of the trawl. The 1946 year class thus probably gives the best picture of the early growth.

When comparing the year class 1944 with the year class 1945 we find that there is a difference in the rate of growth. From the material a direct comparison can be made between the two year classes during the period between 16 and 23 months of life. During the whole of this period the mean size of the prawns belonging to the year class 1944 lies constantly about 5 mm above that of the year class 1945. The growth curves of the year classes 1944, 1943, and 1942 have a trend which shows a

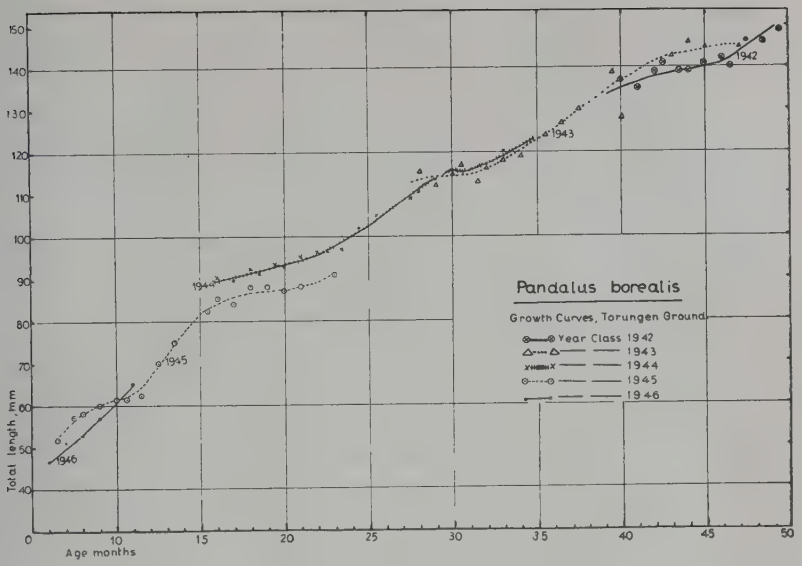

Fig. 15. Growth Curves of the Various Year Classes of Prawns on the Torungen Ground.

natural continuation from the one into the other. All year classes show a partly stagnation of growth in winter (November—April).

A general picture of the life history of the prawn on the Torungen ground is given in fig. 16. The figure is composed from fragments of the various year classes as they are found in different samples. The heights of the columns give the number of individuals in per cent of the total sample, while the bottom figures give the total length.

On the bottom left we find the 6 months old prawns measuring about 50 mm. When 12 months of age they have reached the size of about 70 mm, and when 18 months old their size is about 90 mm. The majority of the prawns are at this age active males. A few individuals (3,5 per cent) develop, however, into females at this age. These young females we find on the right-hand side of the group, and we may assume that it is the most fast-growing individuals within a year-class which have the tendency to become females at an early age. The mean size of the young females lies 5—10 mm above that of the males of the same age (fig. 16 D, E).

A couple of months after spawning (fig. 16, F, G) the male group splits into two fractions, one retaining the male characters, the other entering the transition stages. Again it is the largest individuals in the

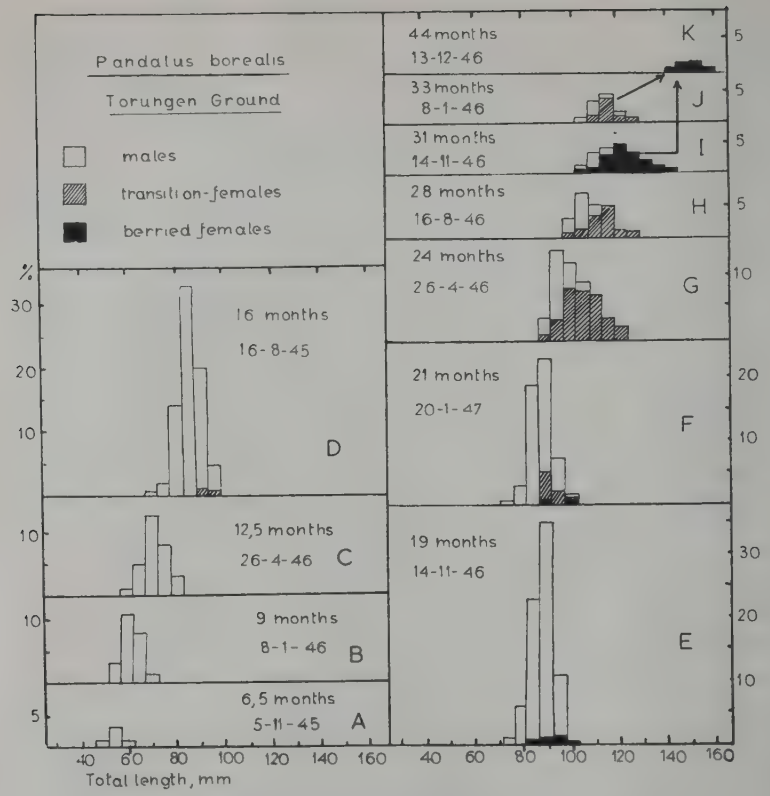

Fig. 16. A General Picture of the Growth and Development of the Prawn on the Torungen Ground.

group which change their sex and become females, while the smaller ones remain males. This division is clearly defined at an age of 24—28 months. By the next spawning season, at an age of 31 months, (fig. 16 I) the female fraction has attained a size of 120—124 mm while the males of the same age have a mean length of only 107—108 mm. These latter are acting in their male capacity for the second time.

The percentage of prawns developing into females at an age of $2^1/_2$ years may differ in the various year classes. Thus of the prawns born in 1944 between 70 and 80 per cent become females when $2^1/_2$ years old, while only 40—50 per cent of the year class 1943 become ovigerous at that age.

At an age of 33 months the last remaining males have started to change their sex (fig. 16 J). When 35 months old all of them have entered the transition stages. They spawn as females for the first time at an age of 3½ years. Their size overlaps that of the second time female spawners which at that age have attained a size of about 140 mm. The life history of the prawn on the Torungen ground can be traced till an age of 50 months when the individuals have reached a size of about 150 mm.

The Life History of the Deep Sea Prawn in the Vigra Fjord.

A preliminary report on the life history of the deep sea prawn in the Vigra Fjord was published in Norwegian by the present author in 1945. The following chapter is largely a revision and a summary of the main features reported upon in said publication.

The Prawn Ground.

In the Vigra Fjord we find quite a large prawn field with rather hard bottom. The main prawn ground is situated between the islands of Vigra and Lepsøy on the west coast of Norway (appr. position 62° 34′ N. Lat. 6° 10 E. Long). The main prawn field in the fjord extends for about 4 miles in a north-south direction, and has a width of 1,5 n. miles on an average. South of the main prawn field we find two smaller grounds separated from the latter and from each other by stony areas (fig. 17).

Generally the prawn fishery on the various grounds in the Møre district has a more or less seasonal character. However, in the Vigra Fjord seasonal stops in the fishery occur rather seldom. According to the fishermen's experience the prawns may periodically be missing from certain parts of the prawn field, and this is particularly noticeable at the extreme northern and southern ends of the ground. Generally, prawn trawling is carried out in depths between 130 and 200 meters. Among fishermen the shallowest part of the fjord alongside Vigra Island is recognized as a locality where small prawns generally are numerous. On the east side of the fjord the bottom is quite uneven with »mountains and deep valleys« as the fishermen say. Here good catches of large prawns can be made in periods when they show tendency to dissappear from other parts of the fjord.

Fig. 17. Chart Showing the Prawn Grounds of the Vigra Fjord.

The central and deepest part of the prawn field often gives poor catches in November and December.

Besides the prawns, the fishermen in the Vigra Fjord catch a small quantity of marketable fish in the trawl, such as cod, haddock and whiting. Of non-marketable fish the *Gadus esmarkii* is the most numerous.

As regards the hydrographic conditions in the Vigra Fjord these are very little known. The prawn field is surrounded by shallow areas on three sides. Only at the north-western entrance there is a channel deeper than 50 meters which possibly leads to the open sea outside. Observations on temperature and salinity confirm the supposition that warm atlantic water mixed with coastal water can penetrate into the fjord

and form the bottom water in which the prawns live. On January 21st 1944 a hydrographic station was taken in the middle of the fjord. The temperatures and salinities in the different depths are listed in table XV.

TABLE XV. Vigra Fjord

Depth m	Temperature °C	S o/oo
0	6,01	32,21
10	6,08	—
25	6,08	,32
50	6,73	33,39
75	6,82	,52
100	7,07	,78
150	7,34	34,33
200	7,32	,33

The Material.

Samples of the deep sea prawn from various localities in the Møre district have been collected by NILS A. FARSTAD, a prawn fisherman from Kjerstad near Ålesund. While carrying out his ordinary commercial trawling he has taken samples from 3 different grounds (the Vigra Fjord, Mi Fjord and the Vannylvs Fjord). However, it is only in the Vigra Fjord that the samples have been taken continuously over such a long period of time that they can form the basis for a closer investigation of the life history of the prawn in this district. The samples were sent to the Institute for Marine Research in Bergen where they were handled in the usual way.

From the Vigra Fjord we have at our disposal 8 samples of prawns containing a total of 4020 individuals. The size of each sample and the dates of capture are shown in table XVI.

TABLE XVI. Vigra Fjord

Date	No. of prawns
Sept. 26. 1943	519
Okt. 1 8. »	534
Nov. 6. »	628
Des. 22. »	294
Jan. 12. 1944	461
March 6. »	633
April 3. »	568
May 2. »	383
Total	4020

It will be noticed that the samples do not cover all months of the year, as material from June, July and August is lacking. In the Vigra Fjord it has, as on many other occasions, proved difficult to collect a completely satisfactory material from a specific prawn ground by the aid of commercial fishermen only. In the practical prawn fishery the fishermen seldom keep on fishing on one and the same fishing ground during the whole year. Through experience they know where the fishing will be most satisfactory in the different seasons, and they direct their operations accordingly. Very often the prawn fishermen may also change over to one or another of the seasonal fisheries carried out in their particular district.

The handling of the material and the study of the growth and development of the prawn in the Vigra Fjord have been carried out along the same lines as discussed in earlier chapters. In the Vigra Fjord material we have to deal with 3 different year classes, born respectively in 1941, 1942 and 1943. Each year's brood can be followed from September one year till May the next. If set up in a continuous row according to date, the different broods may be treated as being parts of a single year-class. By this procedure, however, the contingent yearly variations in rate of growth and development are not properly expressed. In the case of the Vigra Fjord prawn such yearly variations apparently have been rather small among the broods here discussed.

Spawning and Hatching.

The spawning of the deep sea prawn in the Vigra Fjord begins in September. In a sample from September 26th altogether 25 per cent of the females are berried. The ovaries of the rest of the females are fully mature, and they will probably spawn in the very near future. About 10 per cent of these latter individuals have completed their last moulting before spawning, and the pleopods are covered with the conspicuous setae to which the eggs become affixed during spawning. On October 18th we find that 90 per cent of the females have spawned, and 3 weeks later (Nov. 3rd) all females in the sample have completed the spawning and are ovigerous. We may conclude that the spawning of the deep sea prawn in the Vigra Fjord starts about the middle of September and lasts till the end of October.

As usual the eggs are carried all winter till hatching starts by next spring. In the material we find a few non-berried individuals with setae on the pleopods on December 22nd and January 12th, but these are probably prawns which have lost their eggs. The true hatching of the eggs does not begin till a couple of months later. On March 6th we

find that the eggs have hatched in 8 per cent of the females, and a month later, on April 3rd, we find that the eggs have hatched in 95 per cent of the females. At the latter date half of the females have also moulted after hatching. Only 5 per cent of the females are still berried. On May 2nd we find that the eggs in all the females have hatched, and the majority of the prawns have also moulted after hatching. Presumeably the hatching of the eggs starts about March 1st and is concluded by the middle of April.

Summarily we can say that spawning in the Vigra Fjord is finished by the end of October and that the brood is hatched by April 15th. The intervening ovigerous period thus covers about 5½ months. This refers to the conditions found in autum of 1943 and spring of 1944. The possibility cannot be excluded that the dates for respectively spawning and hatching may shift somewhat one way or another in different years.

In previous chapters is reported upon the periods of spawning, egg-bearing and hatching in the Oslo Fjord and the Torungen districts. It is of interest to compare these data with those found in the Vigra Fjord (table XVII).

TABLE XVII. Vigra Fjord

Locality	Spawning		Hatching		Ovigerous period months
	Date	Duration months	Date	Duration months	
Oslo Fjord	1/10—15/12	2,5	1/3—15/5	2,5	5
Torungen	1/10—15/11	1,5	1/3—15/4	1,5	5
Vigra Fjord	15/9—30/10	1,5	1/3—15/4	1,5	5,5

In the Vigra Fjord the spawning seems to occur earlier than in the two other localities. The hatching is completed at the same date as in the Torungen area, but earlier than in the Oslo Fjord. The duration of the ovigerous period is about two weeks longer in the Vigra Fjord than in the other localities. In this connection it must be emphasized that the Vigra Fjord material covers only one spawning and hatching season, while the fixing of the dates for the other localities is based upon several years.

Growth and Sexual Development.

In our material we have some specimens from the early bottom stages of the prawn. Young prawns measuring 37 mm and upwards are present in a sample from the Vigra Fjord captured on September 26th and

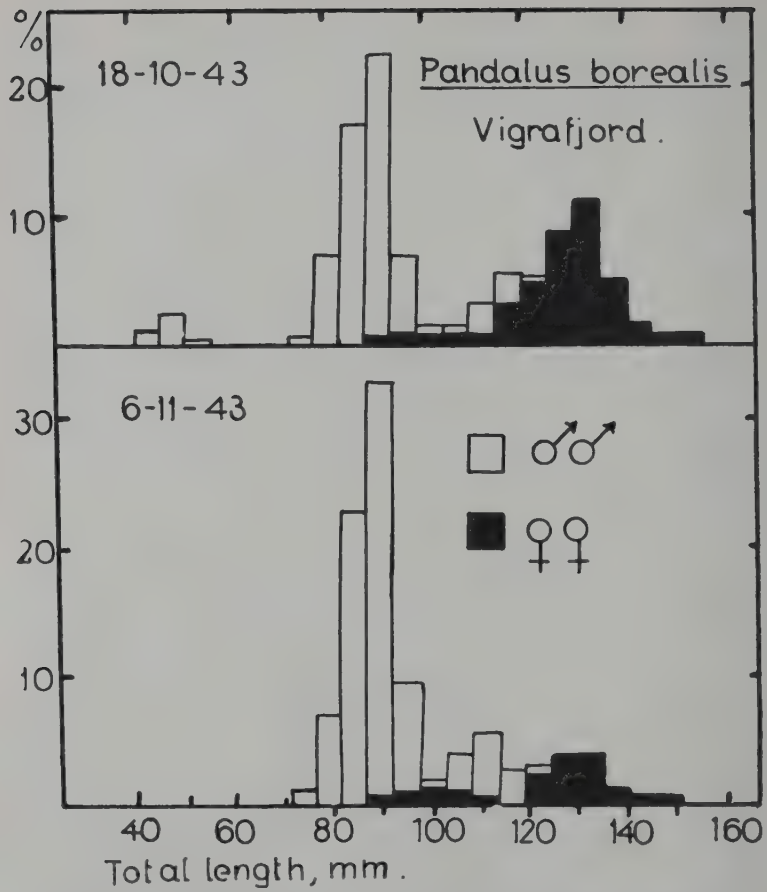

Fig. 18. The Size Distribution of Prawns in Two Samples from Vigra Fjord Taken in Autumn 1943.

November 18th 1943. In the first sample we find 4 young prawns constituting a separate small size group in the measurement series. Fig. 18 gives an impression of the size distribution of prawns in a couple of samples taken in late autumn of 1943. On the extreme left of the figure for October 18th there is a small group of youngs having a mean total length of 46,38 mm. This is the same group as that mentioned above from September 26th, which consisted of only 4 specimens with a mean

length of 43,73 mm. These small individuals in all probability represent the brood born in the spring of 1943, and they are now about half a year old.

The details of the subsequent growth and development of the prawn from the Vigra Fjord are listed in table XVIII. As shown in the table the material contains 3 different year classes, each of which contributes its part towards the construction of the life history of the prawn. In fig. 19 is shown in diagrammatic form the main points of the life history. The white columns in the figure represent youngs and males, shaded columns the transition animals, and black columns the females. The heights of the columns represent the number present in the sample, The heights of the columns represent the number present in the sample, expressed in per cent.

During the first part of their life the prawns have a comparatively rapid growth. At an age of one year they have reached a size of 68 mm (fig. 19 B). This is as far as we can trace the growth of the prawns belonging to the year class 1943.

The continuation of the life history is marked by the year class 1942, which in the autumn of 1943 is about 18 months old. At this age the prawns has reached a size of about 88 mm. At the end of September 1943 we find that the vasa deferentia of the 18 months old prawns are ripe and filled with sperm.

We are able to ascertain that the majority of the prawns in the Vigra Fjord function as active males for the first time when 1½ years old. However, in our samples we find some individuals which do not function as males at this age, but mature instead as females.

When we study the size composition of the prawns as illustrated in fig. 18, we will find between two groups of males (white columns) a small but conspicuous group of under-sized females (black). This group of small females is distinctly separated from the large ovigerous prawns found at the extreme right of the figure. The small ovigerous prawns are individuals which are transformed into females at an early age without first having functioned as males.

We are able to trace this group of premature females from April 3rd in one year till May 2nd in the following (fig. 19 B—F). At first we find a group of small transition animals (B, shaded columns). These are now about one year old, and the endopodites of the first pair of pleopods show that the transformation has taken place after the male characteristics have been formed, but before the individuals have reached the stage of male sexual maturity, i.e. they are secondary females. The transformation from male to female is completed during the summer. In September 1943 we find the same group of prawns with mature ovaries,

and in October the prawns are ovigerous (fig. 19 C). We find them all winter as small-sized ovigerous prawns, and in March—April 1944 the eggs are hatching. In May 1944 the eggs in all the small females have hatched, and the majority of the prawns have also moulted after hatching (fig. 19 F, black columns).

TABLE XVIII. Vigra Fjord

Date	Age months	no. of prawns	Males		Trans.-females		Ovigerous females		Females, eggs hatched		
			%	size	%	size	%	size	%	size	
Year class 1943											
Sept. 26.1943	5,5	4	100	43,73	—	—	—	—	—	—	43,73
Oct. 18. »	6	20	100	46,38	—	—	—	—	—	—	46,38
Jan. 1.1944	9	5	100	62,54	—	—	—	—	—	—	62,54
March 6. »	10,5	96	100	66,41	—	—	—	—	—	—	66,41
April 3. »	11,5	152	98,7	68,37	1,3	82,15	—	—	—	—	68,53
May 2. »	12,5	114	94,7	72,48	5,3	89,23	—	—	—	—	73,35
Year class 1942											
Sept. 26.1943	17,5	344	99,4	88,03	—	—	0,6	95,50	—	—	88,09
Oct. 18. »	18	292	97,9	87,72	—	—	2,1	98,05	—	—	87,93
Nov. 6. »	18,5	477	96,2	88,03	—	—	3,8	100,70	—	—	87,98
Des. 22. »	20,5	270	47,4	88,09	50,4	93,86	2,2	98,95	—	—	91,21
Jan. 12.1944	21	419	65,6	88,30	33,4	94,50	1,0	98,05	—	—	90,47
March 6. »	22,5	524	63,2	88,14	35,8	98,21	1,0	87,98	—	—	91,74
April 3. »	23,5	390	47,5	92,59	51,5	103,40	—	—	1,0	95,40	98,21
May 2. »	24,5	227	41,5	96,46	55,0	108,49	—	—	3,5	102,03	103,30
Year class 1941											
Sept. 26.1943	29,5	171	47,4	110,93	—	—	52,6	129,80	—	—	120,26
Oct. 18. »	30	222	15,3	112,84	—	—	84,7	129,64	—	—	126,88
Nov. 6. »	30,5	151	51,6	111,35	—	—	48,4	129,90	—	—	120,31
Des. 22. »	32,5	23	—	—	56,5	114,16	43,5	135,15	—	—	123,60
Jan. 12.1944	33	37	—	—	83,8	114,53	16,2	126,30	—	—	116,44
March 6. »	34,5	13	—	—	69,2	116,02	30,8	125,88	—	—	120,04
April 3. »	35,5	26	—	—	30,8	122,59	—	—	69,2	129,53	127,41
May 2. »	36,5	43	—	—	—	—	—	—	100	126,43	129,43

From April till October, the period in which the young transition animals mature into females and ultimately spawn, the prawn grows from 82 to about 98 mm. During the ovigerous period from October till April next spring we should normally expect no growth as no moultings take place in this period. The calculated mean lengths show variations between 89 and 101 mm in the individual samples during the

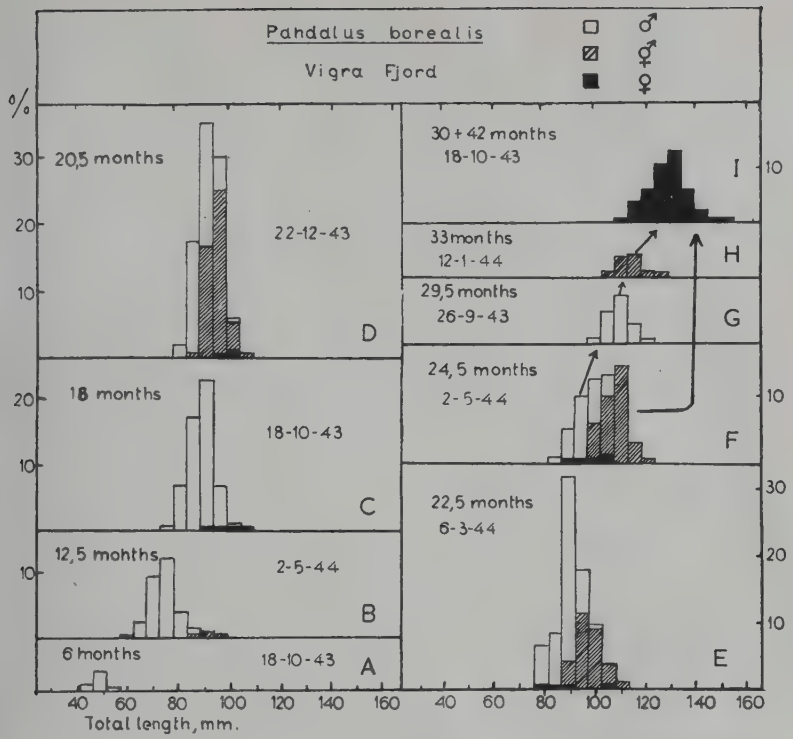

Fig. 19. The Growth and Development of the Prawn from Vigra Fjord.

ovigerous period. This variation in size cannot be considered unduly great, taken into account the small number of prawns of this category present in the samples. The mean size of all the young females during the ovigerous period November—April is 97,84 mm.

From fig. 19 it will be seen that the curve representing the size distribution of the group of young females is displaced to the right relative to that of the males belonging to the same brood. As in other prawn populations in Southern Norway, treated in preceding chapters, it is noticed that it is the largest individuals belonging to a year class which show the tendency to become sexually mature females at an age of $1\frac{1}{2}$ years. To distinguish these early female spawners from those which become sexually mature later in life, the former will be refered to as spawning group ♀ I.

In the Vigra Fjord we are not able to trace the spawning group ♀ I after the eggs have hatched in spring, i.e. after they are two years old.

Their numbers are small, only between 1 and 5,3 per cent of the whole year class. After the first ovigerous period some of them probably disappear from the catches due to natural death. Others will perhaps continue to grow and mature again for spawning next autumn. In the latter case they obviously will intermix in size with older spawning groups from which they cannot be distinguished by external characters.

As mentioned in previous chapters young prawns conforming to the type of «primary females» ware found in the Oslo Fjord, and this type of young female spawners had also been found by JÄGERSTEN to be quite common in the Gullmar Fjord in Sweeden. In the Vigra Fjord the »primary females« have not been found. As far as can been ascertained the spawning group ♀ I in this locality is composed from "secondary females" only. They are first detected in the samples as transition animals, i.e. they have had male characters which are at the point of being reduced.

While studying a closely related species of prawns — *Pandalus montagui* — JÄGERSTEN found that in this species the quite numerous primary females had a more rapid growth than the normal hermaphroditic animals. In the Vigra Fjord we find the same tendency also in the "secondary females" of *Pandalus borealis*. The normal hermaphroditic animals in the Vigra Fjord function as males when $1^1/_2$ years old and at a size of 88 mm. Those animals which mature as females at this age grow more rapidly in the same space of time and attain a size of 96 mm upon spawning. The same accelerated growth of the early female spawners was also found in the Oslo Fjord and on the Torungen ground.

We have thus far discussed the growth and development of the prawn till an age of $1^1/_2$ years when the great majority of the age group function as males. We may now return to the males and discuss their further development with due reference to table XVIII and fig. 19.

During the season when prawns belonging to the year class 1942 are sexually mature males — in October and November 1943 — we cannot register any particular growth. Apparently no moulting takes place at this stage, and growth ceases for a short period of time. At the end of December the development of the male group takes a course which is similar to that found on the Torungen ground. The group of prawns which recently have been active males suddenly splits into two fractions, one fraction retaining the male characters, the other changing into females (fig. 19 D).

In the samples from November 6th 1943 the prawns of the year class 1942 have their ordinary male characters. On December 22nd we find that about one half of the prawns suddenly exhibit the characters of transition animals with the endopodite of the first pair of pleopods dege-

nerating. The other half of the group does not show any sign of transition and retains the male characters. This state of sexual division is found constantly in the samples all winter till May 2nd 1944. At this date the prawns destined to become females have largely completed the transition.

It will be seen that this sexual division within a prawn group again takes place according to the rule that the largest individuals of the age group transform into females while the smaller prawns remain males.

In April and May 1944 the composition of the material shows that on the average 53 per cent of the year class will mature as females when 2½ years of age while 45 per cent remain males. The missing two per cent constitute the early spawners belonging to spawning group ♀ I.

This is exactly the same phenomenon as was found to occur in the Oslo Fjord in certain years, and likewise on the Torungen ground. Whether the division in the Vigra Fjord prawn population may give identical percentages of males and females in all years is of course not possible to ascertain from the scanty material. From another year class, that of 1941, we may, however, obtain an indication. When the year class is approaching an age of 2½ years in the autumn of 1943, we find that in 3 different samples between 48 and 85 per cent (average 64,5) of the prawns become ovigerous, while the rest function as males.

We have no prawn samples from the period June—August and are thus unable to trace the development of the year class 1942 in the following summer. However, from our knowledge of the general life history of the deep sea prawn we may infer that the female fraction of the age group gradually will mature during this period.

The spawning proper and subsequent development are demonstrated by the year class 1941. At the end of September 1943 we find the prawns of this year class, both males and females, ready for spawning. Thus in the autumn we have a spawning population of 2½ year old prawns, one part of which consists of large females becoming ovigerous at this age for the first time, the other part being composed of smaller prawns functioning as active males for the second time (fig. 19 G—I). The females becoming ovigerous for the first time 2½ years of age may be referred to as spawning group ♀ II.

The mean size reached by spawning group ♀ II in the autumn cannot be stated with exactness. This spawning group intermixes with other female spawning groups from which they cannot be separated by external characters or by size. All spawning females form a single size group with a mean size of about 130 mm.

The male fraction of the year class 1942 has in May 1944 at an age of two years reached a size of about 96 mm (fig. 19 F). That is as far as the males of this year class can be followed in the material. The

further development is illustrated by the year class 1941 (table XVIII). Presumeably the males have a comparatively rapid growth during the summer from May till September—October. In late fall the presence of sperma in vasa deferentia shows that the active males are ready for spawning. Thus these individuals spawn for the second time, as males at an age of 2½ years. At this age they have reached a size of about 112 mm (October 18th 1943). The female fraction of the same brood had at the same age reached a size of about 130 mm.

After the male prawns have spawned in late fall the individuals gradually loose their male characters during the following winter and transform into females (fig. 19 H). As the last members of the brood these prawns now definitely conclude their male existence. From table XII it will be seen that the transformation of the males starts in December. Upon entering the transition stages the growth rate becomes more rapid. From January on this fraction of the brood becomes rather scarce in the catches, and after April we loose all track of them as a separate group. Thus in March the sample contains only 9 individuals with a mean size of about 116 mm which presumeably belong to this group, and on April 3rd are found 8 prawns having a mean size of about 123 mm, which probably also belong to this group. These prawns are by now 3 years old.

It may be assumed that these last members of the group will mature as females during the ensuing summer and at the same time steadily increase in size. In the autumn we should in all probability find all of them as ovigerous females. Thus a small number of prawns spawn as females for the first time when 3½ years old. These old females may be classed as belonging to spawning group ♀ III.

The exact mean length of the ovigerous prawns of spawning group ♀ III cannot be determined from the material. In size they will fall within the size limits of spawning group ♀ II and older prawns spawning for a second time. Apparently, the individuals becoming ovigerous for the first time when 3½ years old reach the same size as those spawning as females when 2½ years old, i. e. about 130 mm.

On the Division of an Age Group.

The fact that a group of prawns can split into two fractions — males and females — at a certain point in life, has been mentioned both in the case of the Oslo Fjord and the Torungen area. In the Vigra Fjord prawn population this division within a year group is very clear-cut, and may be discussed in more detail.

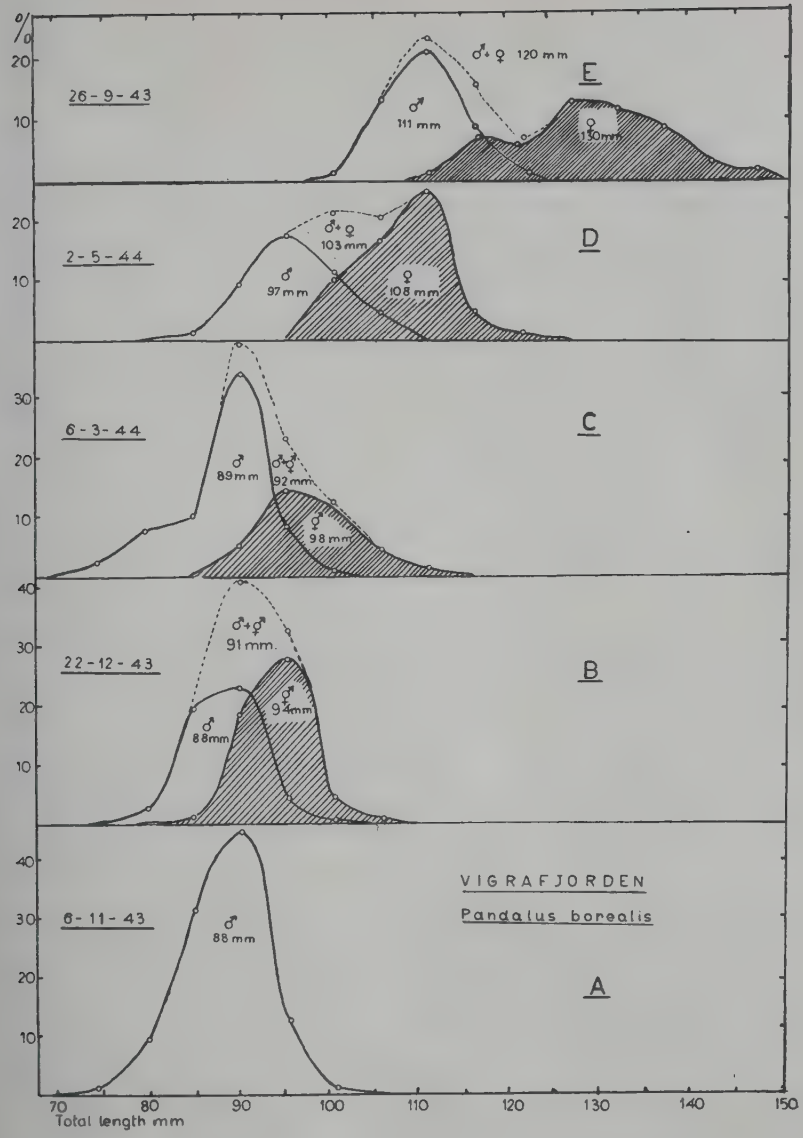

Fig. 20. Group of Male Prawns (A), the Separation of a Female Fraction (B), and the Subsequent Growth of Both Fractions (C.D.E.).

As mentioned on several occasions it is the largest individuals of a group which change into females, while the smaller ones remain males. This splitting up into two sex groups is obviously connected with the attainment of a certain size of the prawn at a certain season of the year. The size which the prawns eventually must obtain before transition into females is not, however, a fixed measurement. Our material shows clearly that the division of a group into two fractions does not occur at a sharply defined size limit. The male fraction and the transitionals form two separate groups which overlap in size. The best impression of this fact is perhaps gained from the illustration fig. 20, where "A" shows the size distribution of the male prawns when spawning in autumn. In "B" division of the group has just taken place. During the subsequent months the two fractions show a steadily increasing difference in mean size, a difference which is caused both by the manner of disintergration and by the difference in rate of growth ("C, D, E").

The animals which remain males show no increase in size during the winter months and it is not until April that we find any appreciable growth. However, it is hardly conceivable that the growth has completely stopped in this period. If the largest individuals of the male fraction steadily enter the group of transition animals during the winter, the mean size of the remaining males should be expected to decrease if no growth took place. Such a decrease in size is not found, and the influence of the departure of the largest males on the mean size of the male group must have been compensated by a contemporary growth among the remaining male prawns. In April and May, none or only few large males seem to leave the male fraction, and this fact, combined with the onset of the natural growth period in Nature, may account for the strongly pronounced growth from April onwards in both fractions.

As regards the female fraction of the group, the individuals here show a small but steady increase in size during winter. The growth rate is probably in reality more rapid than indicated in table XII, but the influx of smaller prawns from the male fraction will tend to diminish the mean values which otherwise would have been found. But from March onwards the growth is rapid, as the influx of small individuals from the male fraction seems largely to have stopped.

From the moment of splitting up on December 22nd till May 2nd the female fraction of the group grows from 94 to 108 mm, an increase of 15 per cent in length. The fraction which contains the males in the same period grows from 88 to 96 mm, an increase of 9 per cent in length. We have the two fractions from year class 1941 present in a sample from September 26th. The male fraction has by then reached a size of 111 mm, and the female fraction 130 mm, i. e. a growth increment of

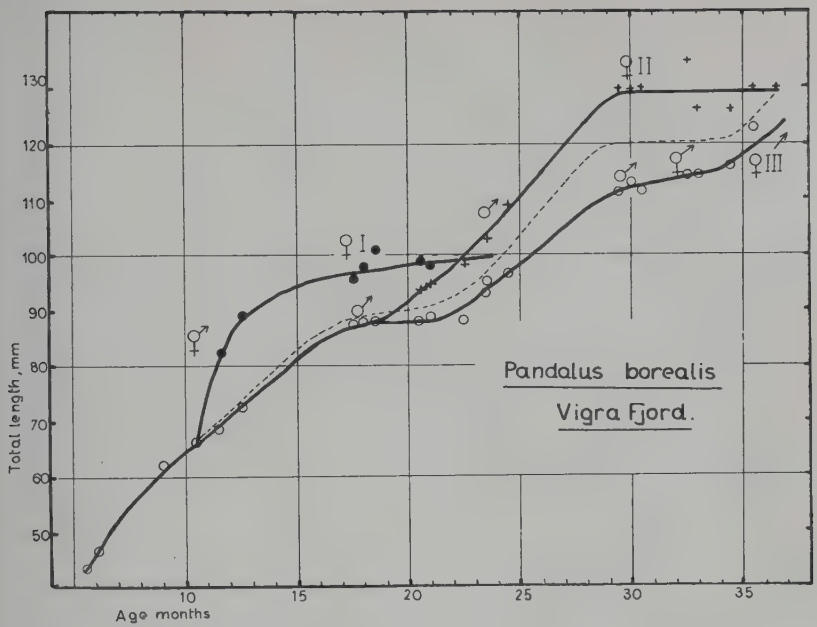

Fig. 21. The Growth Curve of the Various Categories of Prawns in the Vigra Fjord. Broken Line Indicates the Mean Growth.

respectively 12,5 and 38 per cent during the 9 months after the first division (fig. 20 E).

When comparing the mean lengths of the two fractions on the various dates we may conclude that among the prawns of the same age the rate of growth is faster in the fraction becoming females than in that which remains males.

In April and May the difference in size between the two fractions is so great that they easily could be misinterpreted as two different age groups if we had not been able to trace their development during the winter. As illustrated above we have in reality to do with prawns born in the same year which on account of their development form two size groups, one containing small individuals (males) and another group of large and fastgrowing individuals (females).

Summary of Life History.

In fig. 21 is shown the growth curve of the deep sea prawn from the Vigra Fjord. With reference to this figure the life history can briefly be recapitulated.

The youngs are hatched some time during March and early April. When one year old the young prawns have grown to about 68 mm. A few individuals now separate themselves from the group and begin to develop as females becoming ovigerous at an age of 1½ years and a size of 96 mm (spawning group ♀ I). The majority of the group, however, are functioning as active males at this age. These latter individuals are smaller, measuring only about 88 mm.

In midwinter, a short time after spawning, the male group splits into two fractions, one retaining its male characters, the other changing into females. This latter female fraction has a faster rate of growth, and the prawns belonging to it become ovigerous when 2½ years old at a size of about 130 mm (spawning group ♀ II). The second fraction of the group consists of individuals which at the same age function as active males for the second time. These, however, have at the age of 2½ years reached a size of only 111 mm. Finally these old males will change into females and become ovigerous for the first time when 3½ years old (spawning group ♀ III).

The population of ovigerous prawns which we find in the trawl catches from the Vigra Fjord in late autumn and during the winter consists of individuals of greatly varying size and age. The egg-bearing prawns include members which have become ovigerous for the first time when respectively 1½, 2½, and 3½ years of age, and older prawns having spawned before. Theoretically the composition of the stock of ovigerous prawns can be set up in the following way:

Age		1½ years spawning	2½ years spawning	3½ years spawning	4½ years spawning
Spawning group	♀ I	1. time	2. time	3. time	4. time
—»—	♀ II		1. time	2. time	3. time
—»—	♀ III			1. time	2. time

The different spawning groups do not occur with the same strength in the catches. We find only few members belonging to spawning group ♀ I. The spawning group ♀ II is strongly represented, while the group ♀ III again is small. Still older females are very scare.

The mean lengths of the ovigerous prawns in the different samples are shown in table XVIII. As may be expected the size of the ovigerous prawns is fairly constant all winter as the animals do not moult in this period. The mean size of the ovigerous prawns in all samples is 129,74 mm. Among the ovigerous prawns we find a few individuals reaching a size of 159 mm. These individuals are probably older prawns having spawned as females once or twice before.

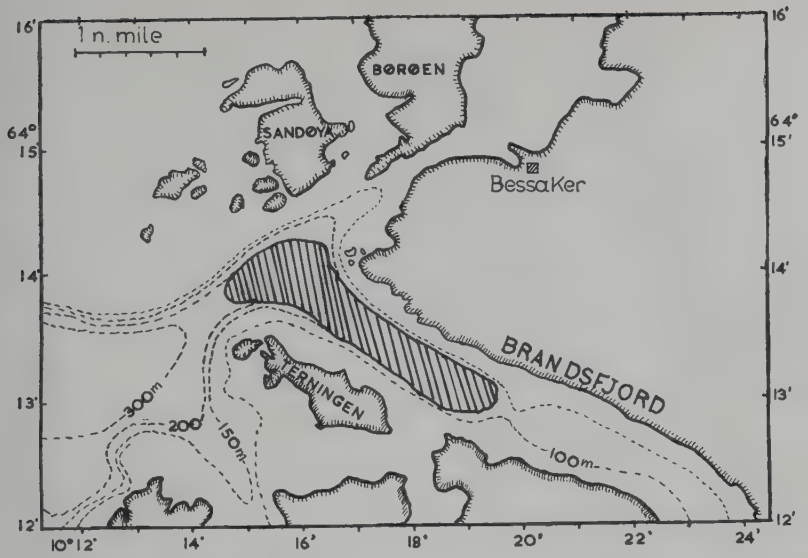

Fig. 22. Chart Showing the Prawn Ground in the Brands Fjord.

On the Deep Sea Prawn from the Brands Fjord.

The Prawn Ground and the Material.

The Brands Fjord trawl ground is a rather small field which is fished by a few prawn trawlers from the nearby port of Bessaker. The prawn field proper is situated in the middle of the fjord and can be fished a short distance outside the entrance (fig. 22). The usual fishing depth within the fjord is 160—170 meters increasing to 225 meters outside the entrance. The approximate position of the prawn field is 64° 13,5′ N. la. 10° 17′ E. long.

As will be seen from the sketch map, there is no treshold at the entrance of the fjord. We have no hydrographic data from this locality, but presumeably the conditions would be very similar to those found in the Vigra Fjord further south. Warm water of Atlantic origin found in the deeper strata outside will meet no hindrance in entering the fjord. As in other fjords of similar type in this part of Norway, the bottom temperatur may perhaps vary between 6 and 8° C during the year. The temperature conditions are for the prawn in this case much the same as found in the prawn fields of Torungen and the Vigra Fjord.

Samples of the deep sea prawn from the Brands Fjord area have been collected by Mr. ERLING SÖRENG, a prawn fisherman from Bessaker.

During his ordinary commercial trawling he has at intervals taken samples from various localities in this area, using a fine-meshed cover over the codend while dragging for the samples.

The most complete collecting of samples has been undertaken in the Brands Fjord, and the material from this locality has therefore been chosen to give a picture of the development of the prawn in this part of Norway. The samples from the fine-meshed net were preserved separately in order to obtain a picture of the composition of the prawns usually escaping from the net in ordinary trawling.

From the Brands Fjord ground we have at our disposal 28 prawn samples containing a total of 15310 individuals. A list of the samples is given in table XIX.

TABLE XIX. Brands Fjord

Date	Number of prawns in	
	Ordinary trawl	Fine-meshed net
Febr. 12.1944	266	210
Marcd 3. »	236	248
March 18. »	503	420
April 26. »	276	450
March 10. 1945....	254	315
March 28. »	303	242
April 17. »	401	638
May 5. »	340	—
July 19. »	265	248
Aug. 30. »	255	172
Sept. 17. »	275	196
Oct. 18. »	308	—
Nov. 10. »	253	199
Des. 5. »	273	262
Des. 22. »	283	507
Jan. 16. 1946....	331	476
Febr 6. »	216	575
March 23. »	136	324
Sept. 23. »	167	141
Oct. 17. »	231	118
Nov. 12. »	143	187
Nov. 30. »	166	381
Des. 19. »	225	189
Jan. 23. 1947....	173	385
Febr. 8. »	196	493
March 7. »	198	181
April 1. »	193	468
April 27. »	253	166
Total	7119	8191

At the laboratory in Bergen the samples were handled in the usual way. In determining the mean lengths of the various groups of prawns, the material from the ordinary trawl and that from the fine-meshed net has been combined in order to obtain the most correct figures.

Spawning and Hatching.

The material permits an examination of the spawning seasons in the autum of 1945 and 1946.

Spawning 1945: In a sample from August 30th all females have ripening ovaries. On September 17th all females have fully developed ovaries, but no spawning is observed. On October 18th only 41 per cent of the females have become ovigerous, 4 per cent have setae on the pleopods and will probably spawn in the immediate future, while 55 per cent show no sign of immediate spawning. On December 5th 18 per cent of the females were ovigerous, while a fortnight later all females were berried.

Spawning 1946: In a sample from September 23rd all females have maturing ovaries. On October 17th only two per cent of them have become ovigerous, while another two per cent have setae on the pleopods and are thus ready for spawning. On November 12th 21 per cent, and on November 30th 94 per cent of the females are berried. On December 19th all females have become ovigerous.

The spawning season seems to be very much alike in the two years. We may assume that spawning starts about October 15th, and is completed by December 15th, i.e. a spawning season of approximately two months. The hatching of the eggs can be followed through 3 seasons.

Hatching 1944: In a sample from March 3rd all females (131 ind.) are carrying their eggs. Only in one specimen the eggs have hatched, or more probably, have been lost. On March 18th the eggs have been hatched in 0,9 per cent of the females. On April 26th the eggs have hatched in all the females. The presence of setae on the pleopods in 52 per cent of the females indicates that hatching has taken place quite recently in the latter case, while the rest have moulted after the hatching of the eggs.

Hatching 1945: In a sample from March 10th the eggs have hatched in 8 per cent of the females. In a sample taken 18 days later the percentage has increased to 13. On April 17th the hatching is completed and 6 per cent of the females have also moulted after the hatching.

Hatching 1946: In a sample from March 23rd the eggs have hatched in only two per cent of the females.

Hatching 1947: In a sample from March 7th the eggs have hatched

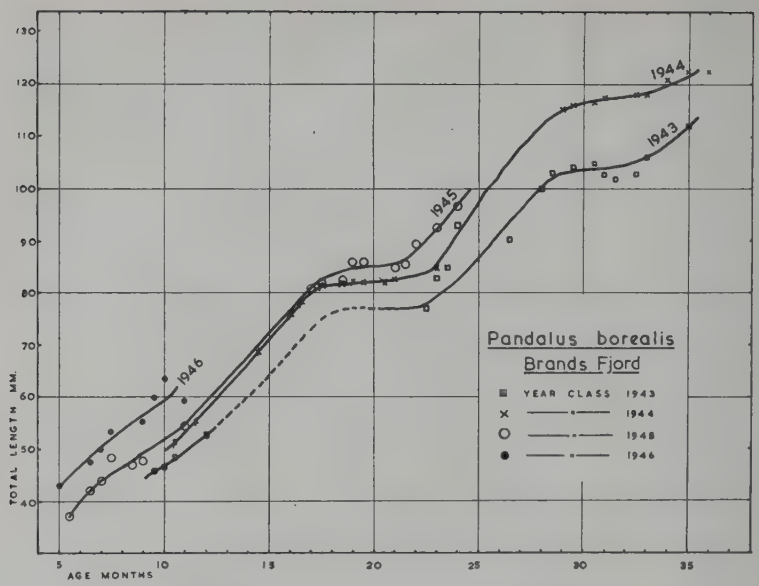

Fig. 23. The Mean Growth Curves of the Various Year Classes of Prawns in the Brands Fjord.

in 5 per cent of the females, and a month later (April 1st) the hatching is still very low, only 11 per cent. In the last sample taken in this locality on April 27th the hatching is almost completed, and only one per cent of the females is still retaining the eggs.

The hatching apparently varies somewhat from one year to another, but largely it lasts from early March till the latter part of April, i. e. a period of approximately 1½—2 months. In most years the hatching seems to be completed by April 15th, but in 1947 the hatching was retarded and was not ended till the end of April. The complete ovigerous period, reckoning from the end of spawning (Dec. 15th) till the end of hatching (April 30th), should thus normally not exceed 4½ months.

Growth and Sexual Development.

The material from the Brands Fjord covers a period of more than 3 consecutive years, from February 12th 1944 till April 1st 1947. The

most serious break-off in the collecting of samples occurred from April 26th 1944 till March 10th 1945. However, in the material we find 4 different year classes, which we are able to trace for a shorter or longer period of time. Together they help towards the reconstruction of the complete life history of the prawn in this locality.

The sexual development of the prawn from the Brands Fjord is very similar to that found in the Vigra Fjord. The details of the life history are given in the tables XX, XXI, XXII and XXIII, which comprise the year classes of respectively 1946, 1945, 1944, and 1943.

It may suffice in this case to treat all year classes at one and the same time, and give only the general outline of the life history, stressing the points where special features appear. The mean growth curves of the various year classes have been drawn in fig. 23.

All the year classes show a different rate of growth from early life. At an age of about 11 months the prawns of the 1946 class have reached a size of about 60 mm, while the prawns of the 1943 class are only about 50 mm at the same age, a difference in size of 10 mm which is very conspicuous for the deep sea prawn. At the same age the year classes 1945 and 1944 have a size of approximately 55 mm. The initial slow growth rate of the 1943 year class is maintained also later in life.

When 18 months old the prawns are spawning as males. On the more southern prawn grounds, discussed in preceding chapters, it was the general rule that a small proportion of the prawns at that age matured as females. In the Brands Fjord this early maturing of females apparently is more of an exception than a rule. In the year class 1945 none of the 18 months old prawns spawned as females. In the 1944 year class only one single small 15 months old individual was found which had passed through the last transition stage and thus probably would spawn as female 3 months later. In the 1943 year class a few small berried females were found at an age of 23—24 months. These prawns, constituting 0,7—1,3 per cent of the year class, have in case become ovigerous at an age of 18 months.

Returning to the prawns which were active males when 18 months old, these develop along the same line as found in the Vigra Fjord. When 21—23 months old a division within the male group takes place, one fraction retaining the male characters, the other entering the transition stages. The number of prawns destined to become females seems to vary from one year to another. In the 1945 year class about 46 per cent have entered the transition stage at an age of 24 months.

What the percentage actually is upon spawning 6 months later cannot be stated on account of the lack of further samples, but presumeably it will be somewhat larger than the 46 per cent mentioned. In the last samples

Year class 1946.

TABLE XX. Brands Fjord

Date	Age months	No. of prawns	Males		Total mean size · mm
			%	size mm	
Sept. 23. 1946....	5	7	100	43,14	43,14
Nov. 12. »	6,5	43	100	47,59	47,59
Nov. 30. »	7	186	100	49,93	49,93
Des. 19. »	7,5	88	100	53,58	53,58
Jan. 23. 1947....	9	294	100	55,39	55,39
Febr. 8. »	9,5	434	100	59,89	59,89
March 7. »	10	126	100	63,44	63,44
April 1. »	11	439	100	58,83	58,83

referred to, taken on April 27th 1947, 36 per cent of the transition annials are in stage B, i. e. they have recently gone through the first change from male to female. In other words, the change of sex has not terminated as yet, and probably still more of the males will change into females during the coming months.

Of the year class 1944 we find that, in the samples from September 23rd till November 12th, on the average 86 per cent have entered the transition stage, and become ovigerous females when 2½ years old (spawning group ♀ II).

The year class 1943 shows a different picture. The prawns destined to become females have largely entered the transition stage before the middle of July. In the period from July 19th till the spawning time (Nov. 10th) on the average 54 per cent of the year class ripen as females and become ovigerous, while 46 per cent function as males for the second time.

We thus find a great difference in the development of the two year classes. Of the 1944 year class 86 per cent mature as females when 2½ years of age, while of the 1943 year class only 54 per cent become ovigerous at the same age. The small percentage of 2½ years old females in the year class 1943 may possibly be related to the general slow rate of growth of this year class from early life. Presumeably the size reached at a certain age has a certain influence on the splitting up. A fast rate of growth apparently gives a larger number of ovigerous females at the age of 2½ years than does a slow growth rate.

The reason for this variation may be found in yearly changes in the environment. We have, however, no hydrographic observations from

Year class 1945.

TABLE XXI. Brands Fjord

Date	Age months	No. of prawns	Males		Transition females		Total mean size mm
			%	size mm	%	size	
Oct. 18. 1945	5,5	7	100	37,10	—	—	37,10
Nov. 10. »	6,5	79	100	42,14	—	—	42,14
Des. 5. »	7	89	100	44,10	—	—	44,10
Des. 22. »	7,5	341	100	48,60	—	—	48,60
Jan. 16. 1946	8,5	330	100	47,06	—	—	47,06
Febr. 6. »	9	421	100	48,28	—	—	48,28
March 23. »	11	215	100	54,59	—	—	54,59
Sept. 23. »	17	210	100	81,20	—	—	81,20
Oct. 17. »	17,5	218	100	81,99	—	—	81,99
Nov. 12. »	18,5	182	100	82,52	—	—	82,52
Nov. 30. »	19	178	100	86,28	—	—	86,28
Des. 19. »	19,5	225	100	85,81	—	—	85,81
Jan. 23. 1947	21	174	97,7	81,57	2,3	90,10	84,80
Febr. 8. »	21,5	159	90,0	87,77	10,0	90,79	85,64
March 7. »	22	167	59,8	86,23	40,2	94,71	89,62
April 1. »	23	139	53,9	88,78	46,1	97,20	92,64
April 27. »	24	131	54,3	92,23	45,7	102,56	96,62

the Brands Fjord and are thus unable to illustrate specific alterations in this particular locality. However, as will be related in a later chapter (see the Vest Fjord), there was a heavy influx of cold bottom water along the coast of Northern Norway in the period 1940—1943, with the lowest temperatures ever observed occuring in 1942. In 1944—45 the conditions again returned to normal. The prawns born in 1943 thus presumeably must have lived under rather severe conditions during the first year of life, while the 1944-class has lived under improved temperature conditions. This variation in the temperature of the bottom water may account for the difference in growth and sexual maturing observed in the two year classes. The mean size of the prawns belonging to the year class 1944 is 116 mm at an age of 2½ years, while that of the 1943 year class is only 104 mm.

This discrepancy in size is also noted in the separate fractions of the prawns which are functioning as males for the second time at an age of 2½ years. The males of the 1944 year class have at this point a mean length of 103 mm, while those of the year class 1943 only measure 96 mm. A few months later these old males enter the transition stage. In the

Year class 1944.

TABLE XXII. Brands Fjord

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
March 10. 1945....	10,5	153	100	51,68	—	—	—	—	51,68
March 28. »	11	129	100	54,61	—	—	—	—	54,01
April 17. »	11,5	511	100	55,54	—	—	—	—	55,54
July 19. »	14,5	272	99,6	68,95	0,4	79,50	—	—	68,95
Aug. 30. »	16	189	100	75,84	—	—	—	—	75,84
Sept. 17. »	16,5	279	100	78,71	—	—	—	—	78,71
Oct. 18. »	17,5	139	100	82,10	—	—	—	—	82,10
Nov. 10. »	18,5	163	100	82,15	—	—	—	—	82,15
Des. 5. »	19	217	100	82,36	—	—	—	—	82,36
Des. 22. »	19,5	253	100	81,99	—	—	—	—	81,99
Jan. 16. 1946....	20,5	227	100	81,94	—	—	—	—	81,94
Febr. 6. »	21	224	87,9	81,30	12,1	93,44	—	—	82,79
March 23. »	23	150	84,5	82,57	15,5	97,68	—	—	84,85
Sept. 23. »	29	91	17,6	102,66	82,4	117,93	—	—	115,28
Oct. 17. »	29,5	128	14,8	102,93	85,2	118,30	—	—	116,02
Nov. 12. »	30,5	104	10,6	102,61	—	—	89,4	118,40	116,67
Nov. 30. »	31	53	11,3	105,10	—	—	88,7	119,20	117,61
Jan. 23. 1947....	33	90	15,6	106,00	1,1	111,30	83,3	120,15	117,82
Febr. 8. »	33,5	96	8,3	106,69	4,2	106,00	87,5	119,57	117,93
March 7. »	34	89	—	—	6,8	111,30	93,2	121,53	120,84
April 1. »	35	81	—	—	—	—	100	122,48	122,48
April 27. »	36	156	—	—	—	—	100	122,43	122,43

1943 class they can be traced only till an age of 35 months as their number decreases rapidly in the samples. Apparently only a few of them reach the point where they become ovigerous females for the first time at an age of 3½ years (spawning group ♀ III).

In the Brands Fjord we find that different year classes can show a great variation in growth and sexual development. Similar variations have previously been pointed out in the Oslo Fjord. Also in the latter locality the year class 1943 showed a retarded growth and a very slow sexual development.

Summary of Life History.

In the Brands Fjord we find that prawns becoming ovigerous when 1½ years old are rather an exception.

Year class 1943.

TABLE XXIII. Brands Fjord

Date	Age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Febr. 12.1944	9,5	106	100	46,27					46,27
March 3. »	10	172	100	46,53					46,53
March 18. »	10,5	430	100	48,71					48,71
April 26. »	12	407	100	52,95					52,95
March 10.1945	22,5	227	87,2	76,06	11,5	84,38	1,3	90,10	77,17
March 28. »	23	285	60,7	79,45	38,6	88,46	0,7	87,45	83,00
April 17. »	23,5	470	62,1	80,45	37,2	93,17	0,7	88,35	85,22
May 5. »	24	198	49,5	85,38	50,5	100,06			92,80
July 19. »	26,5	264	43,9	87,08	56,1	92,70			90,05
Aug. 30. »	28	238	55	93,02	45,0	108,44			100,12
Sept. 17. »	28,5	192	46,8	94,66	53,2	110,56			103,09
Oct. 18. »	29,5	170	44,2	96,51	55,8	110,24			104,20
Nov. 10. »	30,5	211	41,7	95,77			58,3	111,67	105,05
Des. 5. »	31	229	59,4	96,14			40,6	112,31	102,71
Des. 22. »	31,5	195	63,1	95,98			36,9	111,62	101,76
Jan. 16.1946	32,5	249	52,6	95,77	3,7	97,73	43,7	116,20	102,82
Febr 6. »	33	143	21,7	94,71	7,7	97,31	71,6	110,98	106,48
March 23. »	35	95	6,3	99,80	3,2	100,97	90,5	113,47	112,25

When 2½ years of age between 54 and 86 per cent of the prawns mature as females, the number varying in the different year classes.

When 3½ years of age apparently all prawns have changed into females.

The rate of growth can vary from one year class to another. When 2½ years of age a year class having a comparatively slow rate of growth produces a smaller number of ovigerous females than does a year class with a more rapid growth.

On the Deep Sea Prawn from the Mist Fjord.

The Prawn Ground.

The Mist Fjord is a comparatively long and narrow fjord cutting into the mountainous mainland a little north of the city of Bodø. The prawn field is situated in the inner and deepest part of the fjord in the approximate position 67° 26,7′ N. lat. 14° 53′ E. long. (fig. 24). The depth on the trawl ground proper is between 240 and 265 meters. The

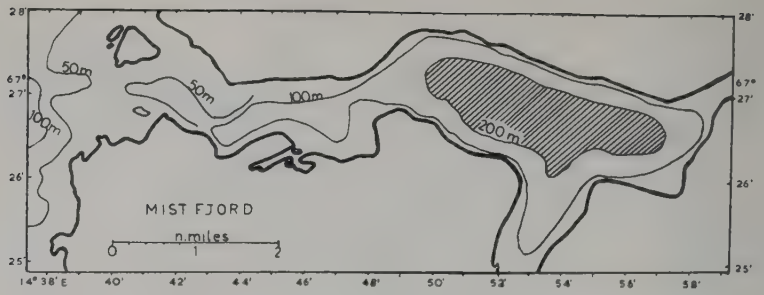

Fig. 24. Chart Showing the Prawn Field in the Mist Fjord.

size of the prawn field is about 4 miles in length and less than one mile in width. The bottom bed is composed mainly of soft bluish-grey clay. During our visits to the fjord a few hydrographic stations were taken in the middle of the prawn field. The data from these stations are listed in table XXIV.

TABLE XXIV Mist Fjord

Depth m	Febr. 1. 1944		Sept. 29. 1945		Oct. 1. 1947	
	t° C	S°/oo	t° C	S°/oo	t° C	S°/oo
0	4,74	32,87	9,36	32,91	9,90	31,57
10	4,74	,91	9,29	—	10,53	,66
25	4,86	,86	9,53	33,15	11,66	32,48
50	5,45	33,05	7,77	,58	10,98	33,06
75	6,01	32,92	5,57	,85	6,18	34,01
100	5,80	33,58	5,47	,90	5,52	,08
125	5,47	,69	5,33	34,04	5,26	,16
150	3,93	34,10	5,19	,11	5,16	,19
200	3,49	,25	4,10	,29	4,88	,24
250	3,40	,23	3,66	,33	4,18	,30

Although the hydrographic observations are scattered we get an impression of the general conditions prevailing in the fjord. In summer the surface water attains relatively high temperatures, but the influence of the summer heating is not felt below a depth of 100 meters. Both in winter and in late summer the temperatures below 100 meters are much the same and show little seasonal variation. This stability in the temperature conditions is most pronounced in the bottom layer which forms the environment of the deep sea prawn. The lowest bottom temperature

measured is 3,40° C, and the highest is 4,26° C, a variation of only 0,86° C. Temperature observations taken on other occasions show only small variations from those already mentioned.

The temperature conditions on the prawn field must be seen in relation to the general topography of the fjord. Across the entrance of the Mist Fjord we find a shallow ridge having a saddle depth of about 50 meters. This barrier is a hindrance to a direct communication between the deeper layers of warm Atlantic water outside the fjord and the deeper layers in the fjord proper. The warm Atlantic water with salinities above 35 ‰ cannot under normal conditions enter the fjord, and thus we find the fjord filled from top to bottom with less saline water of the coastal type.

The general impression gained from our prawn fishery in this fjord is that the prawns are of rather poor quality, consisting largely of small individuals.

The experience of commercial prawn fishermen is that the prawn population as a whole is rather small, giving unsatisfactory and rapidly declining catches after a short period of fishing. While trawling for prawns, the fishermen in most localities can catch some fish which give them a small additional income. In the Mist Fjord, however, the fishes caught in the trawl are generally too small-sized for the market or of non-commercial species. The data listed in table XXV give an idea of the composition of the catches as recorded in the trawl experiments of our research ship. Each haul is of about one hour duration.

TABLE XXV — Mist Fjord

Date	Prawns liters	Marketable		Non marketable young cod
		Cod no.	Redfish no.	No.
June 11. 1943	80	20	3	66
July 12. »	70	—	—	—
—»—	40	43	—	Few
—»—	20	3	1	5
Febr. 1. 1944	23	7	5	510
—»—	50	13	10	904
Sept. 29. 1945	35	—	—	16
—»—	150	5	—	25
Febr. 26. 1946	60	—	—	1
April 6. »	60	1	—	1

In March and September 1948 our research ship »Johan Hjort« paid one of her visits to the Mist Fjord. The routine trawling experiments gave in March the usual results, while in September the trawl yielded no

catch at all neither of fish nor of prawn. The prawns seemed to have dissappeared from the fjord.

In connection with the hauls the usual hydrographic stations were taken. The observations gave the results shown in table XXVI.

TABLE XXVI — Mist Fjord

Depth m	March 7. 1948			Sept. 27. 1948		
	t° C	S o/oo	Occ.	t° C	S o/oo	Occ.
0	2,80	31,66	7,43	8,40	31,22	6,57
10	3,54	33,26	,14	9,34	32,55	,13
25	3,53	,55	0,6	9,58	33,00	5,40
50	3,79	,94	6,94	8,01	,75	,76
75	3,76	,96	,75	5,41	,98	6,05
100	3,87	,99	,51	4,96	34,03	0,5
125	3,95	34,00	,40	4,75	,04	,00
150	3,99	0,5	,12	4,43	,05	5,81
200	4,08	,09	5,63	4,12	,10	4,28
250	4,26	,23	—	4,18	,35	2,67

As will be noticed neither the temperature nor the salinity of the bottom water showed any unusual features. The oxygen content, however, differed widely on the two occasions. In September the bottom water contained 2,67 cc of oxygen per liter, a saturation of only 30 per cent. In March we have no actual data for the oxygen content in the bottom layer proper, but at 200 meters it was 5,63 cc or 77 per cent. In March the oxygen content was generally higher in all the strata of the sea.

Renewed fishing efforts in 1949 and in October 1950 showed that the prawns were still missing. A hydrographic station taken on October 15th 1950 showed a bottom temperature of 4,24 C and an oxygen content of only 1,09 cc per liter, i. e. even less than in 1948.

The dissappearance of the prawn from the Mist Fjord in the autumn of 1948 is in all probability due to the low oxygen content of the bottom water. The explanation of this disaster to the prawn field is presumeably that the oxygen present in the bottom water has been consumed in the respiration of the living bottom organisms and by the decomposition of dead animals and plants. The great stability of the water in the fjord has hindered the vertical circulation of the water masses while at the same time the barrier at the entrance of the fjord has prevented renewal from outside of the bottom water. Such hydro-

graphic conditions are to be expected in a fjord of this type and, as we have seen, may prove disastrous for the prawn population and the prawn fishery.

The Material.

The material of prawns from the Mist Fjord has been collected intermittently when occasion offered itself. As there is very little commercial trawling carried out in the fjord it proved impossible to contact fishermen for systematic collection of prawn samples. When our research vessel "Johan Hjort" has passed the Mist Fjord on her cruises to and from Northern Norway she has slipped into the fjord in order to take experimental hauls with the prawn trawl in order to capture samples of prawn and young cod. Through a number of years we have in this way been able to collect 8 samples of deep sea prawns containing altogether 5008 individuals. (Table XXVII).

TABLE XXVII. Mist Fjord

Date	No. of prawns
June 11. 1943	691
July 12. »	477
Febr. 1. 1944	604
April 3. »	813
Sept. 29. 1945	618
Febr. 26. 1946	545
April 6. »	892
March 7. 1948	368
Total	5008

The material does not cover all months of the year. The lack of samples in late autumn and early winter (Oct.—Jan.) is a disanvantage, and hampers the analysis of the material to some extent.

The growth and development of the deep sea prawn population in the Mist Fjord have been ascertained by calculating the mean size of the different age groups in each sample. Later on these size groups are listed in a continuous row according to month of capture, the year being left out of consideration. The samples are in this way considered as having been collected all in one year. By such a procedure the estimated mean size of a singel group at the different seasons will be only approximately correct, as variations in growth and maturing which possibly may occur in broods born in different years are not adequately expressed.

Spawning and Hatching.

By studying the sample of prawns from July 12th 1943 we find that the ovaries of the females are ripening, and they have partly developed "roe in the head". At the end of September 1945 about 50 per cent of the females have fully developed ovaries while the rest show a less degree of maturing. No egg-bearing females are found at this date, and spawning has not yet started. Further material for an exact determination of the spawning period is lacking. Presumeably the spawning does not begin till the middle of October. As in other localities the spawning may continue for about 6 weeks. If such is the case all females should be ovigerous towards the end of November.

The egg-bearing period lasts all winter, and its course can be traced in the material. On February 1st 1944 we find prawns with eyed eggs, and early in April the same year hatching of the eggs has just started. In the sample from June 11th 1943 the eggs of all the females have hatched. In 45 per cent of the females hatching must have taken place comparatively recently as the setae on the pleopods, to which the eggs have adhered, are still present and no moulting after hatching has taken place.

The rest of the females in the samples have moulted after hatching. The hatching of the eggs is thus probably completed by the end of May.

In the Mist Fjord we should according to this have a probable spawning period of 6 weeks in autumn, lasting from October 15th till November 30th, and a hatching period of about two months in spring from April 1st till May 30th. The ovigerous period, reckoning from the end of spawning till the end of hatching, should thus cover about 6 months.

The spawning in the Mist Fjord starts in this case a fortnight later than for instance on the Torungen ground and also ends a fortnight later. The duration of the spawning period is the same in both localities. The hatching of the eggs starts a month later in the Mist Fjord, and ends 6 weeks later than on the Torungen ground. Thus we find an egg-bearing period of 5 months on the Torungen ground compared with 6 months in the Mist Fjord. The ovigerous period lasted in the Oslo Fjord for 5 months, in the Vigra Fjord for $5^1/_2$, and in the Brands Fjord for $4^1/_2$ months. In the Mist Fjord the ovigerous period has presumably the longest duration observed so far. The material used for comparison is from different years in the individual localities, and the possibility cannot be excluded that yearly variations in the seasons of spawning and hatching may occur on all prawn fields.

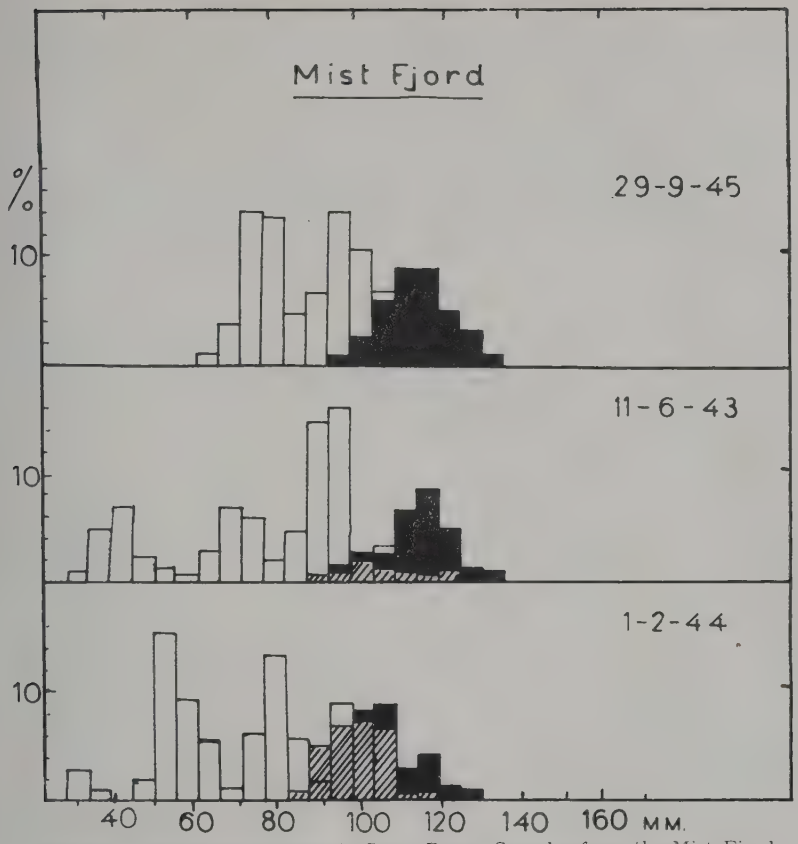

Fig. 25. The Size Distribution in Some Prawn Samples from the Mist Fjord.

Growth and Sexual Development.

After the prawn larvae have hatched in spring they enter their pelagic period of life. How long this pelagic existence lasts we are not able to ascertain. On the prawn grounds in Southern Norway we usually get the small bottom stages of the prawn in samples taken in late autumn. In the case of the Mist Fjord it is not till next winter that we come into contact with the new prawn generation. In February 1944 the first young prawns numbering 19 individuals appear in the trawl. In fig. 25 is shown the size composition of the prawns in a few selected samples from the Mist Fjord. On the extreme left in the figure dated Febr. 1st we

find the young prawns mentioned above as a group with a mean size of 32,65 mm. We may naturally assume that these small prawns were hatched before May 30th 1943 and thus by the present date should be about 8 months old.

Using these small prawns as a starting point we can follow the development and trace the growth by means of the samples taken on the various dates. In table XXVIII are listed the calculated mean lengths of the prawns till they reach an age of 2½ years. May 30th is considered the birth date.

TABLE XXVIII. Mist Fjord.

Date	Age months	No. of prawns	Males	
			per cent	size mm
Febr. 1. 1944	8	19	100	32,65
Febr. 26. 1946	9	36	100	41,66
March 7. 1948	9,5	11	100	40,97
April 3. 1944	10	29	100	37,63
April 6. 1946	10	68	100	43,34
June 11. 1943	12,5	110	100	41,50
July 12. 1943	13,5	175	100	41,71
Febr. 1. 1944	20	198	100	56,24
Febr. 26. 1946	21	150	100	72,48
March 7. 1948	21,5	118	100	62,54
April 3. 1944	22	303	100	62,59
April 6. 1946	22	384	100	76,32
June 11. 1943	24,5	122	100	69,64
July 12. 1943	25,5	77	100	73,51
Sept. 29. 1945	28	206	100	76,43

From the age of 8 till the age of 13½ months the prawns grow from about 33 to 42 mm. The latter prawns were taken on July 12th 1943. A haul made on September 29th 1945 yielded no small prawns, which by now would have been about 18 months old, although they had appeared in quite large numbers on earlier occasions. However, judging by the general growth, as given in the table, the prawns should have reached a size of about 50 mm when 18 months old. Such small-sized prawns are generally immature youngs, and this must be assumed to be the case also in the Mist Fjord. A year later at the same date the prawns have reached a size of about 76 mm. This group of 2½ year old prawns contains individuals measuring between 69 and 85 mm. The condition of the testes were not investigated when treating the sample, but we may assume that the prawns of this size are actively spawning males. In other localities, as for instance in the Brands Fjord in Southern Trøndelag, prawns with

a similar size distribution in autumn had vasa deferentia filled with sperm. In the Mist Fjord we may conclude that the prawns function as active males for the first time in life when 2½ years old.

In the prawn populations of Southern Norway it seems to be a general rule that a small degree of splitting up into males and females occurs at an age of 18 months, and still more so at an age of 30 months. In the Mist Fjord it is significant that no fractioning takes place at any of these points. Apparently the whole year group mature as males when 2½ years of age, no members of the year class becoming ovigerous females at that age.

TABLE XXIX. Mist Fjord.

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Febr. 1. 1944	32	331	57,4	81,70	42,6	99,98	—	—	89,46
Febr. 26. 1946	33	324	56,5	87,61	43,5	102,32	—	—	94,02
March 7. 1948	33,5	234	77	83,95	23	95,08	—	—	86,50
April 3. 1944	34	452	43,6	86,07	56,4	99,96	—	—	93,92
April 6. 1946	34	438	42,5	91,96	57,5	105,05	—	—	99,63
June 11. 1943	36,5	311	85,2	92,06	14,8	105,10	—	—	94,02
July 12. 1943	37,5	162	82,1	94,18	17,9	105,81	—	—	96,30
Sept. 29. 1945	40	412	47,4	95,48	—	—	52,6	113,90	105,10
Febr. 1. 1944	44	56	—	—	—	—	100	114,16	114,16
Febr. 26. 1946	45	35	—	—	—	—	100	110,56	110,56
April 3. 1944	46	29	—	—	—	—	100	112,20	112,20
June 11. 1943	48,5	48	—	—	—	—	100	115,96	115,96
July 12. 1943	49,5	63	—	—	—	—	100	118,88	118,88

After the age of 2½ years the composition of the material at hand allows for two different interpretations of the further growth and development.

The first possibility is illustrated in table XXIX. A few months after having functioned in their male capacity, the splitting up into males and females takes place. In this case we find that in February about 43 per cent of the year class have entered the transition stages. The percentage varies from sample to sample. In June and July, for instance, we find that only about 15 and 18 per cent of the year class will become females next fall. On September 29th the female fraction has again increased to about 53 per cent. But this figure also includes many older spawners, and should in reality be smaller. In this period, between the age of 32 and

40 months, the males grow from 81,7 to 95,5 mm, an increment of 13,8 mm or 16,9 per cent. The females in the same period show an increase in mean length from 100 to maximum 114 mm, an increment of 14 mm or 14 per cent. The significance of these figures will be touched upon below.

If the prawn has a development as described above, we should at the age of 3½ years find a single year class composed of two groups, viz. one group of males spawning actively for the second time at a mean size of 95,5 mm, and another group of females becoming ovigerous for the first time at a size of 114 mm. The mean size for the whole year class at the age of 3½ years is in the case 105,10 mm.

The male fraction is quite numerous at the age of 3½ years, constituting at least 50 % of the year class, and one might have expected them to appear also in later samples. But such is not the case. In the sample from February 1st, 4 months after spawning, and also in later samples no individuals are found which in size and development

TABLE XXX. Mist Fjord.

Date	Appr. age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Febr. 1. 1944	32	190	100	81,70	—	—	—	—	81,70
Febr. 26. 1946	33	183	100	87,61	—	—	—	—	87,51
March 7. 1948	33,5	180	100	83,95	—	—	—	—	83,95
April 3. 1944	34	179	100	86,07	—	—	—	—	86,07
April 6. 1946	34	187	100	91,96	—	—	—	—	91,96
June 11. 1943	36,5	265	100	92,06	—	—	—	—	92,06
July 12. 1943	37,5	133	100	94,18	—	—	—	—	94,18
Sept. 29. 1945	40	195	100	95,48	—	—	—	—	95,48
Febr. 1. 1944	44	141	—	—	100	99,98	—	—	99,98
Febr. 26. 1946	45	141	—	—	100	102,32	—	—	102,32
March 7. 1948	45,5	54	—	—	100	95,08	—	—	95,08
April 3. 1944	46	255	—	—	100	99,96	—	—	99,96
April 6. 1946	46	251	—	—	100	105,05	—	—	105,05
June 11. 1943	48,5	46	—	—	100	105,10	—	—	105,10
July 12. 1943	49,5	29	—	—	100	105,81	—	—	105,81
Sept. 29. 1945	52	217	—	—	—	—	100	113,90	113,90
Febr. 1. 1944	56	56	—	—	—	—	100	114,16	114,16
Febr. 26. 1946	57	35	—	—	—	—	100	110,56	110,56
April 3. 1944	58	29	—	—	—	—	100	112,20	112,20
June 11. 1943	60,5	48	—	—	—	—	100	115,96	115,96
July 12. 1943	61,5	63	—	—	—	—	100	118,88	118,88

correspond to these old males. This is rather curious, and we may look for another solution of the problem of growth and maturing.

As mentioned above the material at hand permitted two different interpretations of the life history subsequent to the age of 2½ years. The second possibility is illustrated in table XXX. With reference to the table the life history may be summarized as follows:

After the spawning in autumn the growth of the prawn continues all through the following year without any change of sex. In the autumn of the next year, when the prawns have reached an age of 3½ years, they are still males and will be actively functioning as such for the second time.

By now they have reached a size of about 95 mm. If such is the case, all individuals belonging to a year class of prawns in the Mist Fjord are active males for two successive seasons, i. e. when respectively 2½ and 3½ years of age.

The transformation of the males into females probably starts a short time after the prawns have had their second active male period, and in the course of the following months the whole year class is transformed into females.

In February and early April most of the prawns are in the first transitional stage (stage B). In June we find all 3 transitional stages represented, and several individuals have also completed their transformation into females.

In July the ovaries are visibly ripening in both the transitionals and in those having completed the transformation. The prawns spawn as females for the first time when 4½ years old at a size of about 114 mm. The ovigerous prawns are found all winter, and as expected they do not seem to have any appreciable growth in the egg-bearing period. The eggs hatch before June 1st. In July nearly all spent females have moulted and by this date they have increased considerably in size, measuring now about 119 mm. Most of these females are maturing again and thus preparing for a second spawning in the autumn.

When the eggs have hatched, the prawns are 5 years old. We are not able to trace the growth much beyond this point with any degree of certainty. When the large prawns have moulted after hatching, they cannot be distinguished satisfactorily from other females having completed their transformation from males. The two groups of females overlap in size and do not show a distinct line of division.

One may ask which is the most probable of the two possible interpretations mentioned above. In my opinion the second solution is the most satisfactory one, on the basis of the following argument:

If a divison within a year group really does take place at an age

of about 32 months, then we should expect that the female fraction had a rapid growth while the growth of the males was retarded during the subsequent months (see chapter on Vigra Fjord prawn).

The retardation of growth in the male fraction is generally due to the fact that the largest individuals of the group enter the transition stage while the small ones remain in the male fraction. This is obviously not the case among the Mist Fjord prawns. After the splitting up, if any, the males show here a rapid growth while the transitionals are retarded in their growth. This contradicts all previous experience from other prawn populations.

Secondly, if a disintegration really did take place, at least 50 per cent of the year class would function ac males for a second time when $3^1/_2$ years of age. If this were the case such a number of large males should easily be traced also in later samples. However, in our material we lose track of them suddenly. It is more probable that all males change their sex during one season, and thus the second interpretation of the life history would seen the most correct one.

Summary.

The growth curve of the Mist Fjord prawn is shown in fig. 26. For comparison is inserted the mean growth curve of the prawn on the Torungen field in Southern Norway.

Assuming that the second interpretation of the life history of the Mist Fjord prawn is the correct one, the growth and development can shortly be summarized as follows:

The birth date of the prawn can be fixed at about May 30th. When 1½ years old they have reached a size of approximately 52 mm. When 2½ years of age the mean size is about 77 mm and the prawns are active males. At the age of 3½ years the prawns are active males for the second time, having reached a mean size of about 96 mm. Soon after spawning the individuals enter the transition stages. When 4½ years of age all the prawns are spawning as females for the first time, and they are egg-bearing individuals during the following winter. Their mean length in this period is 113,42 mm, a rather small size for ovigerous prawns compared with those found on other prawn grounds.

After the eggs have hatched when the prawns are 5 years old, they continue their growth. The growth can be traced till an age of 61½ months when the prawns have attained a size of approximately 119 mm.

The results from a study of the age and the rate of growth of the prawn population in the Mist Fjord confirm the general impression gained while trawling, that the prawns on this ground are rather small-

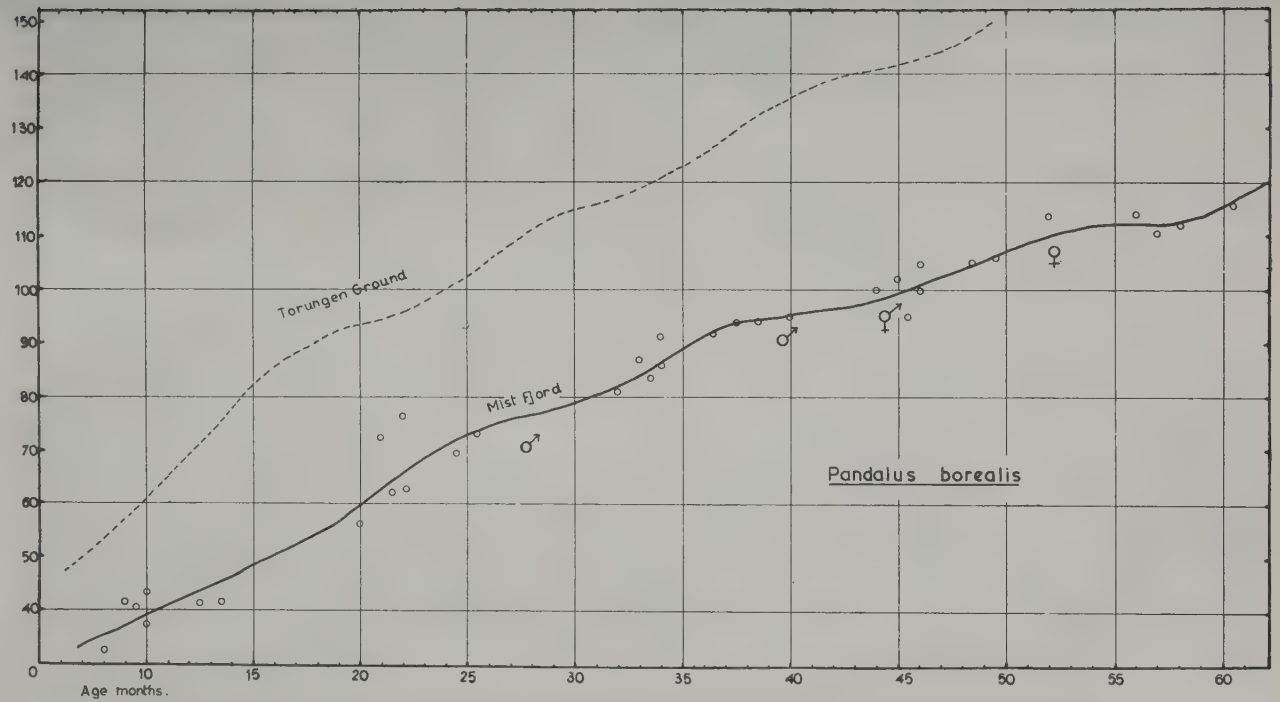

Fig. 26. The Growth Curve of the Prawn in the Mist Fjord. For Comparison the Growth Curve of the Prawn on the Torungen Ground (Broken Line).

sized. Both the mature male prawns as well as the ovigerous females are smaller in the Mist Fjord than in other localities. In this respect a comparison with the prawns from the Torungen ground shown in fig. 26 may illustrate the fact.

In the Mist Fjord we find a slower rate of growth, a retarded maturing, and a longer ovigerous period than in any of the other prawn fields treated before. An explanation of these features may probably be sought in the topography of the fjord and the special hydrographic conditions prevailing on the prawn field.

On the Deep Sea Prawn from the Ofoten Fjord.

The Prawn Ground and the Material.

The Ofoten Fjord is about 35 n. miles long and between 1,5 and 4 miles wide, cutting into the country as an extension of the broad Vest Fjord outside. At the entrance there is no pronounced shelf, the depth here being 200—300 meters. Along the central part of the fjord runs a deep channel between 500 and 600 meters in depth. Towards the inner part of the fjord, when approaching Narvik, it becomes more shallow, and in this region the prawn field is situated in approximate position 68° 27′ N. lat. 17° 20′ E. long. (fig 27).

The prawn field proper is about 6 miles long and has depths of between 200 and 300 meters. This prawn field in the Ofoten fjord is connected with smaller prawn grounds in the Rombaks Fjord and Herjangen Fjord by narrow and deep channels. The Ofoten prawn ground, or the "Narvik Field" as it is also called, is very rich in prawns but difficult to fish effectively. The prawns are commonly caught in a deep channel in the middle of the ground. This channel does not form a straight line but makes several turns. In some places there are crags and other hindrances which may tear the trawl. For this reason it is necessary to navigate according to bearings ashore while dragging.

The prawn fishery in the Ofoten Fjord started about 1935. The fishery proved very rich already from the start and several boats fished this ground till 1940. However, during the war the prawn ground became so littered with wrecks of ships and aeroplanes during the Narvik operations, that it was very difficult to continue the prawn trawling at all.

The prawn field was not fished in 1940—42 and thus received a natural protection for a few years. In 1943 two fishermen tried the field again. They found the prawn population to be very rich, and they could obtain catches of 600 kg in two hours fishing. But due to

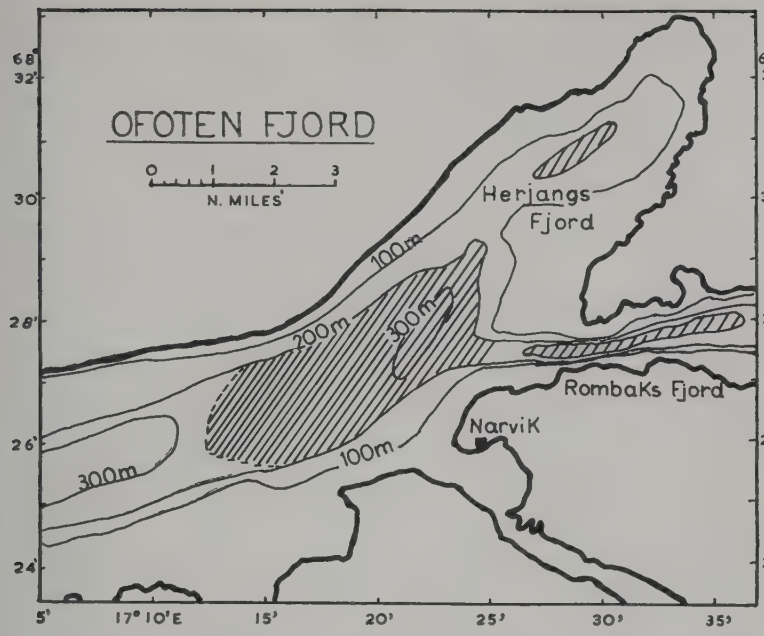

Fig. 27. Chart Showing the Prawn Ground in the Ofoten Fjord.

the foul bottom mentioned above, the gear was severely torn, and one of the boats gave up fishing after having lost all her gear. The other fisherman, Mr. PEDER ASPEVIK, succeeded in finding a channel among the wreckage, and in fixing the proper bearings for fishing the ground. He has since continued the fishery here.

During the summer of 1943 the present author visited the prawn field of Narvik, and had occasion to examine the catches made by Mr. ASPEVIK abord his prawn vessel. Two hauls were made on June 21st, each of 3 hours duration, and one haul in each direction of the field. The contents of the trawl in each case were as follows:

I. 200 liters of large *Pandalus borealis,* 100 large and 6 small redfish *(Sebastes marinus),* 2 boxes (ab. 30 ind.) of large cod, 2 boxes of haddock youngs I—II group.

II. 200 liters of large *Pandalus,* 58 large *Sebastes marinus,* 1 box of cod, 2 boxes of haddock youngs I—II group. Besides the prawns it is particularly the redfish which is of any commercial value in the catch. A noticeable feature of the catch is the unusual amount of young haddock present. According to Mr. ASPEVIK the small haddock can

be quite numerous in some years and then mostly during the summer months, dissappearing more or less from the field in autumn.

An idea of the general hydrographic conditions on the prawn field in the Ofoten Fjord is gained from three stations taken approximately in the middle of the ground. (Table XXXI).

TABLE XXXI. Ofoten Fjord.

Depth	Febr. 28. 1944		March 25. 1946		Sept. 13. 1946	
	Temp.°C	S o/oo	Temp.°C	S o/oo	Temp.°C	S o/oo
0	2,70	32,43	1,95	33,19	10,50	—
10	2,99	,43	2,14	,29	12,24	31,09
25	3,01	,44	1,58	,29	9,79	32,21
50	5,64	,87	1,57	,29	6,53	,64
75	6,71	33,68	5,34	34,05	4,89	33,30
100	6,30	,96	5,98	,37	4,42	,69
125	5,82	34,20	6,13	,51	5,03	34,03
150	5,74	,34	6,27	,68	5,88	,35
200	5,93	,59	6,49	,80	6,51	,72
215	—	—	6,53	,84	—	—
225	—	—	—	—	6,72	,78
250	5,99	,60	—	—	—	—

The Ofoten Fjord has no threshold, and warm and salt Atlantic water found in the deeper layers outside has no difficulty in penetrating to the innermost part of the fjord. The bottom water covering the prawn field is therefore comparatively warm, and the observations show that seasonal temperature variations apparently are very small. The hydrographic conditions in the Ofoten Fjord are rather similar to those found on the prawn grounds in the Vigra Fjord and off Torungen in Southern Norway.

TABLE XXXII. Ofoten Fjord.

Date	No. of prawns
June 25. 1943	438
July 21. »	431
Aug. 15. »	286
Oct. 15. »	792
Nov. 20. »	738
Febr. 26. 1944	493
Total	3178

The prawn material from the Ofoten Fjord consists of 6 samples collected in a period from June 1943 till February 1944 (table XXXII). I owe my sincere thanks to Mr. Aspevik for his kind cooperation in the collecting of the material under difficult conditions.

The material was preserved in formaldehyde and sent from Narvik to the laboratory of the Fisheries Institute in Bergen where it was worked up in the usual way.

Spawning and Hatching.

The material gives only meagre information on the spawning and hatching of the prawn in the Ofoten Fjord. In the middle of August 1943 all females are visibly maturing and have "roe in the head". On October 20th spawning have started some time ago, as we find that 24 per cent of the females are berried and another 9 per cent have pleopods covered with setae, indicating that they will spawn in the immediate future. Exactly one month later 65 per cent of the females are ovigerous, while another 11 per cent are ready for spawning. Due to the lack of samples we are not able to trace the development further than November 20th. Presumeably the spawning of the deep sea prawn in the Ofoten Fjord begins about October 1st and is concluded at the end of November, i. e. a spawning season of two months duration.

We have no data by which we can determine the hatching season in spring, and we are thus also unable to state the duration of the complete ovigerous period. In order to have a starting point for determination of the age of the prawns, May 1st has been chosen as the most probable birth date in this locality.

Growth and Sexual Development.

The material from the Ofoten Fjord contains four different year classes, each of which contributes a part towards the construction of the life history of the deep sea prawn in this locality. All four year classes are represented in a sample from February 26th 1944, the size distribution of which is shown in fig. 28. On the extreme left of the figure is shown the size distribution of the youngest prawns in the material. These prawns vary in size between 32 and 53 mm. Their mean length is 40,17 mm. We may naturally assume that these prawns are born in the spring of 1942 and thus at the date of capture should be 10 months old. For comparison it can be mentioned that the prawns in the Mist Fjord had attained a similar size at the same age.

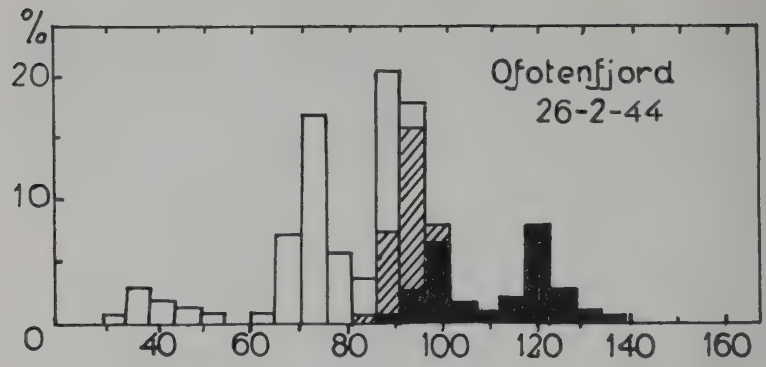

Fig. 28. The Size Distribution and Sex Composition of a Prawn Sample from the Ofoten Fjord. White Columns: Youngs and Males. Shaded Columns: Transitionals. Black Columns: Females.

Using these young prawns as a starting point we are able to trace the subsequent growth and sexual development through the different samples. In table XXXIII are listed the calculated mean lengths of the prawns with increasing age. The growth curve is given in fig. 31.

The life history of the prawns from the Ofoten Fjord shows many traits which we find among prawns from other localities. Between the age of 10 and 14 months the prawn grows from about 40 to 63 mm. By November, when 1½ years old, the prawns have grown to about 72 mm. As far as can be determined the whole year class at that age consists of active males. We find no individuals maturing as females at that age.

In other prawn populations we have seen that about two months after the spawning the group of males divides in such a way that a part of the prawns enter the transition stage while the other part remain males. In the prawn population of the Ofoten Fjord such a division has not yet occurred at the end of February when the prawns are 22 months old. But a splitting up within a year class does occur also in this locality, but it is apparently more retarded than in other localities. Thus we find in the year class 1941 that 18,8 per cent of the prawns have entered the transition stage when 26 months old. In the subsequent samples the relative number of transition animals varies a great deal.

Between the age of 26 and 34 months we find that on the average 11,6 per cent of the prawns have left the male group. They spawn as females when 2½ years old, while averagely 88,4 per cent of the same year class function as males for the second time at that age.

TABLE XXXIII. Ofoten Fjord.

Date	Age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Year class 1943									
Febr. 26. 1944	10	24	100	40,17	—	—	—	—	40,17
Year class 1942									
June 25. 1943	14	60	100	62,54	—	—	—	—	62,54
July 21. »	14,5	82	100	64,45	—	—	—	—	64,45
Aug. 15. »	15,5	25	100	70,38	—	—	—	—	70,38
Oct. 20. »	17.5	82	100	72,19	—	—	—	—	72,19
Nov. 20. »	18,5	89	100	72,35	—	—	—	—	72,35
Febr. 26. 1944	22	155	100	74,47	—	—	—	—	74,47
Year class 1941									
June 25. 1943	26	334	81,2	87,50	18,8	89,84	—	—	87,93
July 21. »	26,5	263	83,3	88,73	16,7	99,96	—	—	90,68
Aug. 15. »	27,5	166	92,2	92,38	7,8	101,50	—	—	93,07
Oct. 20. »	29,5	538	94,6	92,40	—	—	5,4	100,70	92,80
Nov. 20. »	30,5	444	93,3	92,69	0,2	95,40	6,5	102,50	93,17
Febr. 26. 1944	34	246	35,8	92,53	42,6	93,81	21,6	100,33	93,97
Year class 1940									
June 25. 1943	38	54	—	—	48,2	123,81	51,8	128,15	126,14
July 21. »	38,5	86	—	—	51,2	121,90	48,8	128,31	125,03
Aug. 15. »	39,5	95	—	—	—	—	100	127,94	127,94
Oct. 20. »	41,5	172	—	—	—	—	100	126,14	126,14
Nov. 20. »	42,5	204	—	—	—	—	100	125,29	125,29
Febr. 26. 1944	46	68	—	—	—	—	100	123,07	123,07

The mean size of the spawning males is about 92 mm, while the individuals of the female fraction have attained a mean size of approximately 100 mm. As in other localities we thus find that the females are larger than the males after the division of the age group. The females do not show any increase in size after they have become berried. As regards the males of the year class 1941, they show only a small growth in winter between the age of 30 and 34 months. As soon as the spawning period is over a second division of the male group is started. At the end of February 1944, when the prawns are 34 months old, we find that more than half of the group have entered the transition phase. Four months later the rest of the group have also joned the transition animals. The calculations of the mean lengths show that in the period between the age of 34 and 38 months, the growth of the transition animals is unusu-

ally rapid. From February till June they grow from about 94 mm to 123 mm; an increase in size of 29 mm.

The calculations show a similar rapid growth also among the females during the same period. When ovigerous, they measure 100 mm, a size which they presumeably also maintain till the eggs hatch in spring. Already a couple of months after hatching, when 38 months old the females show a mean size of about 128 mm, i. e. an increase in length of 28 mm.

This increase in size in both transition animals and female prawns can hardly be considered natural. It may be explained by varying growth rates in different year classes of prawns. The year classes 1943, 1942 and 1941, when listed one after another, show a comparatively natural and even growth and development till the prawns have reached an age of 34 months.

When we thus leave the 1941 year class when 34 months old, and continue the life history of the prawns at a point 4 months later, as illustrated by the 1940 year class, we get great leaps in the figures for the mean size. Apparently the 1940 year class has had a much more rapid growth early in life. A much greater part of this year class must also have matured as females when 2½ years of age. As mentioned above on the average 11,6 per cent of the 1941 year class became ovigerous when 2½ years old. Of the 1940 year class the percentage may have been about 50.

At the age of 3½ years all individuals of the year class 1940 are spawning females. Some of them are at this age becoming ovigerous for the second time; others have just completed the transition phase and are becoming ovigerous for the first time. These two categories of females intermix with regard to size and cannot be separated in the samples. The mean length of the spawning 3½ year old females is 125,56 mm. We can trace the prawns in the samples till they are 46 months old.

We have seen that in the Ofoten Fjord a number of prawns from a year class mature as females when 2½ years old. The proportion of these early females may, however, vary from one year to another. From the 1941 year class averagely 11,6 per cent become ovigerous at that age, while from the 1940 year class the percentage may have been about 50. Such a development is not exeptional for the Ofoten Fjord. A similar variation in the protandric development has for instance been discussed also in the case of the Oslo Fjord.

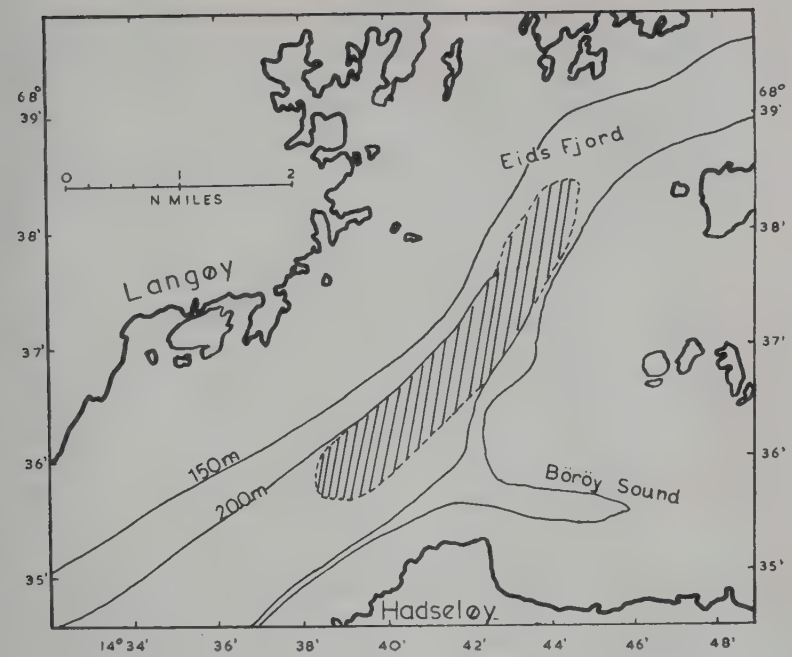

Fig. 29. Chart Showing the Prawn Ground in the Eids Fjord.

On the Deep Sea Prawn from the Eids Fjord.

The Prawn Field and the Material.

The Eids Fjord is a long and narrow fjord cutting into the country as an extension of the open Vesterås Fjord north of the Lofoten Islands. Along the central part of the fjord runs a deep submarine channel which is a direct continuation of the deeper water outside the fjord. The main prawn field of the Eids Fjord, the Dragnes ground, is situated at the entrance of the fjord (fig. 29) where we find an area with soft clay bottom between 200 and 240 meters in depth. A smaller prawn field is also found farther inside in the fjord proper having similar depths (the Vottesnes ground), and a very large and rich field is also found in the same deep channel farther out in the open sea (the Gaukværøy ground).

The present account deals with the prawn population on the central Dragnes ground, the approximate position of which is 68° 36,5′ N. lat. 14° 41′ E. long. It has not been possible to establish a continuous collection of samples from the prawn grounds in this area as they are only intermittently fished by commercial prawn fishermen. However, several

samples were colected between July 1943 and February 1944 by one fisherman, Mr. Birger Fredriksen from Hanøy, Vesterålen. Some samples have also been secured during the cruises of our research ship "John Hjort". Only a part of the material has been collected continuously over such a length of time that it could form the basis for a complete analysis of the life history of the prawn. All samples used in the following discussion are from the Dragnes ground and are listed in table XXXIV.

TABLE XXXIV. Eids Fjord.

Date	No. of prawns
1. July 9. 1943	550
2. Sept. 7. »	1171
3. Oct. 8. »	1599
4. Oct. 29. »	1794
5. Febr. 10. 1944	722
6. Sept. 21. 1945	519
7. Oct. 17. 1946	404
Total	6759

While taking the samples no. 2—5 a fine-meshed covering was used over the cod-end of the trawl. A part of the catch in the fine-meshed net had become mixed with the sample taken from the ordinary trawl. These samples therefore contain a comparatively large number of young prawns.

The hydrographic conditions on the Eids Fjord prawn ground can be illustrated by a few stations taken in the center of the field at different seasons of the year. (Table XXXV).

TABLE XXXV. Eids Fjord.

Depth m	Febr. 11. 1944		Sept. 20. 1945			Oct. 17. 1946	
	T° C	S o/oo	T° C	S o/oo	Occ.	T° C	S o/oo
0	2,30	32,57	10,04	33,47	6,20	9,75	31,88
10	3,97	33,12	10,15	,48	6,20	10,19	32,04
25	5,15	33,40	10,06	,70	6,18	10,85	,91
50	5,48	,63	7,44	34,04	6,22	11,03	33,31
75	5,80	,75	6,72	,28	6,13	11,09	,35
100	6,69	34,10	6,86	,69	6,10	—	,78
125	6,60	,17	6,86	,73	6,87	9,08	34,07
150	6,71	,28	6,89	,76	5,87	7,73	,29
200	6,95	,38	6,64	,78	5,94	7,08	,58
215	—	—	—	—	—	7,27	,62
225	7,47	,54	—	—	—	—	—

The temperatures and salinities near the bottom are very similar to those found on the prawn grounds in the open fjords in more southern localities. The Eids Fjord prawn field is covered with comparatively warm and salt water of Atlantic origin mixed with coastal water, conditions which apparently prevail all year round. This is quite natural as there is no threshold or other obstacle which can hinder the penetration of the Atlantic water from the deeper strata outside.

Spawning and Hatching.

In the samples from September 7th 1943 all the females have maturing ovaries. A month later, on October 29th, we find that 20 per cent of the females are ovigerous, another two per cent have the pleopods covered with setae and will spawn in the immediate future, while the rest of the females have "roe in the head". We are not able to trace the spawning any further, as our next sample is from February 10th 1944, a date on which all prawns have been ovigerous for some time.

We have very little material to illustrate the hatching of the eggs. However, an indication of the commencement of hatching is found in a sample taken on the adjacent Gaukværøy prawn ground on March 15th 1944. Of a total of 377 females only one single individual bore the marks that the eggs had hatched recently. Most probably the hatching does not commence in any of these fields before a fortnight later.

The spawning season of the prawns in the Eids Fjord probably lasts from about October 1st till the middle or end of November, i. e. a period of 1½—2 months. The hatching period begins perhaps about April 1st. The duration of the hatching period is not known. With due regard to the general situation of the field and the hydrographic conditions found in the Eids Fjord, we may presume that hatching is mainly completed by May 1st. This date will be used as a starting point in estimating the age of the prawns.

Growht and Sexual Development.

In a sample taken on September 7th 1943 were found two very small individuals measuring about 32 mm in length. We may safely assume that these prawns were born in the spring of the same year and when captured should be approximately 4 months old. From this age onwards we are able to trace the growth and development of the deep sea prawn in this locality.

In figure 30 is shown the size distribution of two samples of prawns, one taken in the autumn and the other in the winter about 5 months

later. On the extreme left of the top figure is drawn the size distribution of the young prawns mentioned above, which belong to the year class 1943. Besides this are 3 other year classes represented in the material. The growth and development of the Eids Fjord prawn are listed in table XXXVI. The growth curve is shown in fig. 31. With reference to the table and figure the life history can be shortly summarized.

TABLE XXXVI. Eids Fjord.

Date	Age months	No. of prawns	Males		Trans.-females		Ovigerous females		Total mean size mm
			%	size mm	%	size mm	%	size mm	
Year class 1943.					—	—	—	—	
Sept. 7. 1943	4	2	100	31,80	—	—	—	—	31,80
Oct. 8. »	5,5	9	100	32,95	—	—	—	—	32,95
Oct. 29. »	6	87	100	39,64	—	—	—	—	39,64
Febr. 10. 1944	9,5	209	100	44,68	—	—	—	—	44,68
Year class 1942.									
July 9. 1943	14,5	483	100	61,27	—	—	—	—	61,27
Sept. 7. »	16	528	100	70,81	—	—	—	—	70,81
Oct. 8. »	17,5	1129	100	72,82	—	—	—	—	72,82
Oct. 29. »	18	973	100	75,58	—	—	—	—	75,58
Febr. 10. 1944	21,5	236	54,2	77,22	45,8	84,54	—	—	78,49
Year class 1941.									
July 9. 1943	26,5	185	44,8	85,44	55,2	91,48	—	—	88,72
Sept. 7. »	28	564	15,6	88,78	84,4	101,44	—	—	99,48
Oct. 8. »	29,5	393	29,8	91,69	70,2	103,09	—	—	99,64
Oct. 29. »	30	639	21,5	91,85			78,5	103,09	100,65
Febr. 10. 1944	33,5	261	0,7	98,05	26,4	94,02	72,9	108,33	104,46
Year class 1940.									
July 9. 1943	38,5	139	—	—	49,0	108,39	51,0	126,72	117,87
Sept. 7. »	40	77	—	—	—	—	100	131,12	131,12
Oct. 8. »	41,5	69	—	—	—	—	100	126,14	126,14
Oct. 29. »	42	89	—	—	—	—	100	130,17	130,17
Febr. 10. 1944	45,5	16	—	—	—	—	100	132,50	132,50

Between the age of 4 and 18 months the prawns grow from 32 to about 75 mm. At the latter age the prawns have a size distribution between 58 and 85 mm. All the prawns between 64 and 85 mm (971 ind.) are sexually mature males, while two individuals measuring 58 mm show no maturing. None of the $1^1/_2$ year old prawns seem to mature as females.

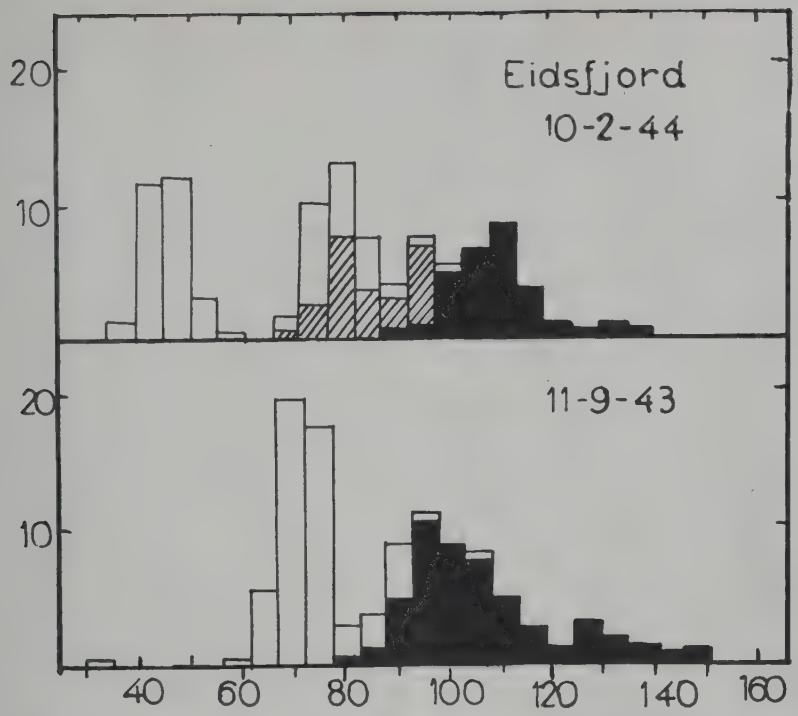

Fig. 30. The Size Disitribution and Sex Composition of a Prawn Sample from the Eids Fjord. White: Youngs and Males. Shaded: Transitionals. Black: Females.

In February, about 3½ months after spawning, we find that the year class has split into two fractions (fig. 30). One fraction constituting 46 per cent is in the transition stage while 54 per cent still have the male characters. It is the largest males which show the tendency to change sex. During the following summer still more of the males enter the transition stages or become females so that at the commencement of the spawning season when the prawns are 2½ years of age, between 70 and 84 per cent, averagely 80 per cent, of the year class are spawning as females. The rest of the year class, 20 per cent, spawn as males for the second time. The female fraction has at this age attained a mean size of approximately 103 mm, while the males measure only 92 mm.

About 3½ months after this second spawning season, at an age of 33½ months, the great majority of these old males have entered the transition stage. We can trace this part of the year class till an age of 38½ months when all of them are transitionals or females with a mean

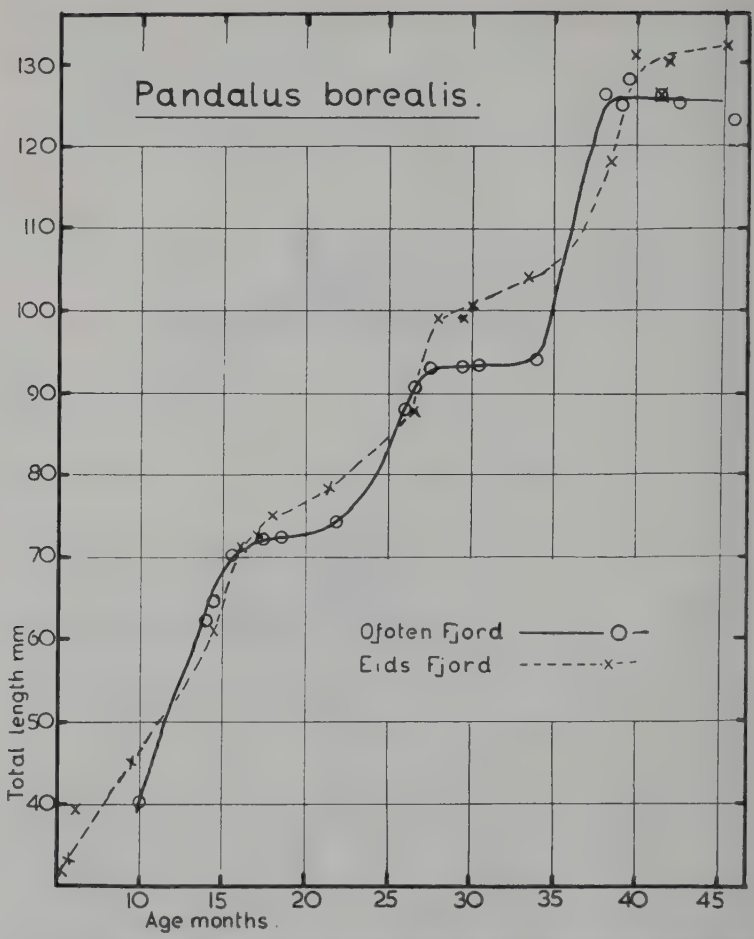

Fig. 31. The Growth Curves of the Prawns in the Ofoten Fjord and in the Mist Fjord.

size of 108 mm. In later samples they intermix in regard to size with females which by now have grown rapidly after the hatching of the eggs from their first ovigerous period. When $3^1/_2$ years of age all individuals of the year class mature as females. The majority of them at this age become ovigerous for the second time in life, while others are spawning as females for the first time. The 3½ years old prawns vary between 122 and 143 mm in length, the mean size being 130,17 mm.

The sexual development of the prawns in the Eids Fjord as illustrated in table XXII is very similar to that observed in some localities in Southern Norway. It can for instance be compared with the year class 1944 on the Torungen ground. In the latter locality, however, variations in sexual development were shown to occur from one year to another. Similar variations may also be expected among the prawns from the Eids Fjord. Thus we find in a sample taken in Eids Fjord on September 21st 1945 that all individuals of the year class 1943 are maturing as females when 2½ years old, none of them spawning as males twice as was the case with the year class 1941. Another sample from the Eids Fjord, taken on October 10th 1946, again contains a few individuals which spawn as males for the second time when 2½ years of age (year class 1944).

It is of interest to compare the life history of the prawn in the Eids Fjord with that of the prawns from the Ofoten Fjord treated in the preceeding chapter. In both localities identical year classes of prawns can be compared. On both prawn grounds the whole year class 1942 is composed of active males of an age of 1½ years. At an age of 2½ years, however, we find a great difference in the development. In the Ofoten Fjord about 88 per cent of the prawns are spawning as males for the second time at that age while only 12 per cent mature as females (year class 1941). In the Eids Fjord, however, only 20 per cent of the same year class function as males for the second time when 2½ years old, while 80 per cent mature as females at that age. In this connection it may be mentioned that although the prawn grounds in both localities are covered by warm Atlantic water, the bottom temperature may on an average be somewhat lower in the Ofoten Fjord than in the Eids Fjord. Thus on February 28th 1944 we find a bottom temperature of 5,99° C in the Ofoten Fjord, while the bottom temperature in the Eids Fjord on February 11th the same year was 7,47° C, i. e. a difference of 1,48° C.

On the Deep Sea Prawn in Spitsbergen and Jan Mayen Waters.

A report, written in Norwegian, on the deep sea prawn in Spitsbergen waters was published by the present author in 1942. The material has since been revised and new samples added. However, the following description is largely a summary of the results published in the report cited, and only minor changes have been made.

The Prawn Fields and the Material.

The collection of prawn samples in Spitsbergen waters has been carried out in conjunction with the practical fishery investigations carried out under the leadership of Captain THOR IVERSEN through a number of years. The zoologist on these cruises, Mag. Scient. EINAR KOEFOED, has kindly placed at my disposal the prawn material which he has collected since 1923. In 1939, 1946, and 1947 the present author had the opportunity to visit Spitsbergen and personally collect samples.

The trawling for deep sea prawns at Spitsbergen has been part of the general plan for fishery investigations in Arctic waters. Every year since 1923 prawn samples have been brought back, preserved in formaldehyde on ½ or 1-liter glasses. The prawns were originally collected with a view to obtain a systematic treatment at the Bergen Museum. Some of the material has also been worked up by JAMES A. GRIEG (1924, 1926, 1932). As the prawn samples originally were not collected with particular regard to the present work, the material often is not as comprehensive as might be desireable. However, in 1939 and partly in 1938 so many and large samples were collected that they could form the basis for a more comprehensive study of the life history of the deep sea prawn in Spitsbergen waters.

The location of the prawn grounds often referred to in the present report is shown in the sketch map fig. 32. At Spitsbergen there are several known prawn grounds, all of them originally located and fished by IVERSEN.

In the Kongs Fjord area we find 3 prawn grounds, namely the Krone Deep, the Kings Fjord Deep and in the Kross Fjord. Prawn trawling has been carried out in the Krone Deep in depths of 277—330 meters, the Kongs Fjord in 258—324 meters and in the Kross Fjord in 331 meters. The Kongs Fjord Deep was fished for the first time in 1936 and has since given satisfactory catches every year.

In the Foreland Sound we find two prawn fields, namely the Poole Deep and the Rekesøyla. The Poole Deep has fishing depths between 200 and 245 meters, and the Rekesøyla 219—260 meters. The latter is one of the richest prawn grounds hitherto located in the Spitsbergen area. Both these grounds were fished for the first time in 1936. In the Ice Fjord there is a comparatively large prawn field in the Karlskrona Deep off Advent Fjord. The trawling depths are here generally 234—262 meters. Also this field was fished for the first time in 1936.

Near the entrance of the Ice Fjord there is a small prawn field in the central part of the Grøn Fjord where the depth is approximately 150—160 meters. This ground was fished for the first time in 1924

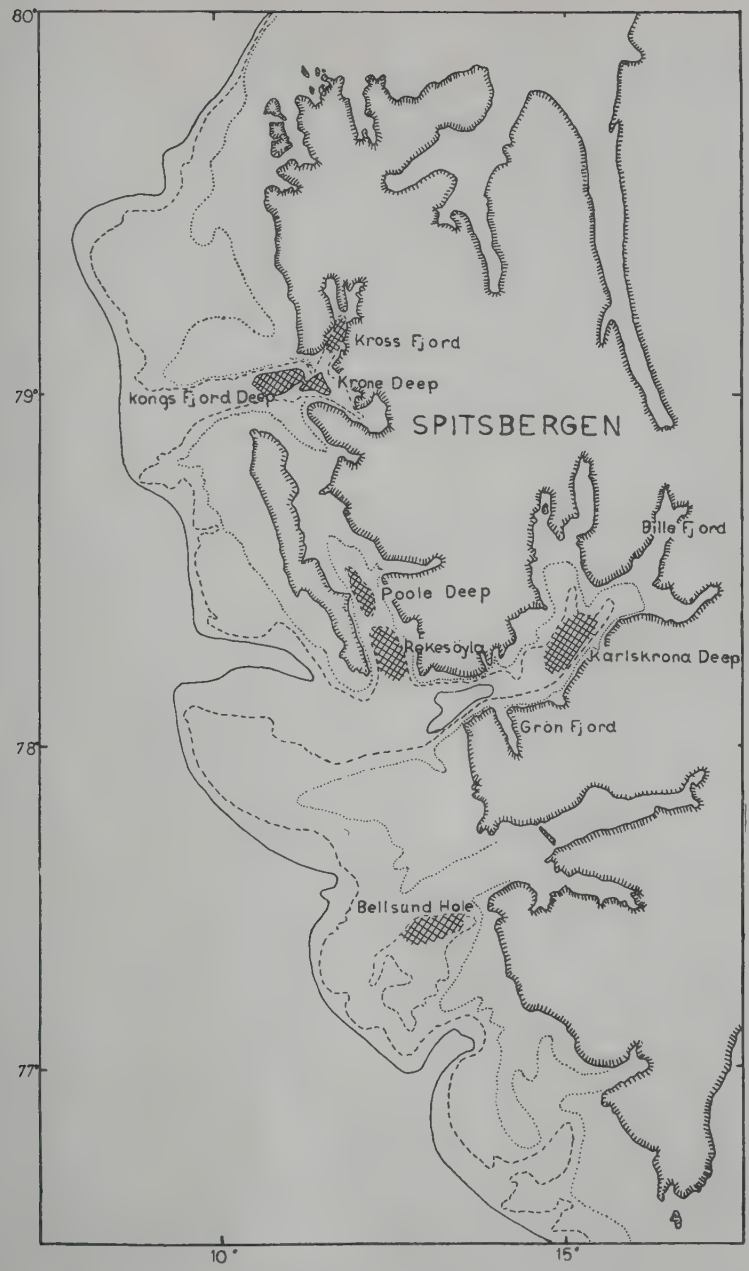

Fig. 32. Chart Showing the Prawn Fields in Spitsbergen Waters.

with good results. Satisfactory catches were also made on this ground the following years till 1931. In 1935 prawn trawling was tried again, but now the catch was insignificant. The prawns must have disappeared from the Grøn Fjord between 1931 and 1935. Yearly fishing experiments proved that the prawn had not returned till the outbreak of World War II.

In 1936 IVERSEN found a prawn field in the Bellsund Hole situated in the open sea. In this locality trawling was carried out in depths between 230 and 237 meters. Trawling for deep sea prawns has also been tried in other localities such as the Advent Fjord, off Coles Bay, Bellsund, Hornsund and the Bille Fjord, with varying success.

The material used in the investigation of the age and rate of growth of the deep sea prawn is shown in table XXXVII.

TABLE XXXVII. Spitsbergen.

Date	Locality	No. of prawns
July 8. 1925	Grøn Fjord	258
Aug. 19. 1936	Rekesøyla, Poole Deep	85
Sept. 28. »	Bellsund Hole	78
Aug. 23. 1937	Rekesøyla	95
May 31. 1938	Karlskrona Deep	101
June 28. »	Krone Deep	158
July 2. »	Kross Fjord	522
July 11. »	Rekesøyla	168
Sept. 3. »	Krone Deep	394
May 26. 1939	Kongs Fjord Deep	112
May 31. »	Rekesøyla	106
June 5. »	»	108
June 22. »	Kongs Fjord Deep	106
June 29. »	—»—	213
July 1. »	Rekesøyla	109
July 7. »	Poole Deep	160
July 21. »	Kongs Fjord Deep	163
Aug. 2. »	—»—	101
Aug. 11. »	Karlskrona Deep	151
Aug. 13. »	Rekesøyla	100
Aug. 30. »	»	82
Aug. 30. »	Karlskrona Deep	142
July 16. 1940	»	66
July 8. 1946	Advent Fjord	350
July 19. »	Rekesøyla	463
Aug. 20. 1947	Rekesøyla	331
Total: 26 samples		4722 prawns

Spitsbergen is situated in the Arctic drift ice area. The fishery investigations in these waters have been carried out mostly in summer when the coastal banks and the fjords are open and free from ice. On this account samples have been collected only in the open season from May till early September and in most years they date from mid-summer. The natural conditions in this area thus limit the possibility of tracing the growth and development of the deep sea prawn throughout the year. As regards the possible course of development in winter we are forced to make the necessary deductions on the basis of material collected in other seasons. The various prawn groups seem to have a constant size distribution whether they are caught early or late in summer. The main reason for this is apparently that the growth is so slow that any increase in length does not appear as statistically significant in the measurement series during the short period of sampling. Another thing to be taken into consideration is the fact that on account of the the scattered sampling we are unable to deal with the growth of one single year class only. In order to determine the growth from year to year the different year classes of prawns have been treated as if they constituted one single year class.

In the Spitsbergen material there has not been any particular difficulty in separating the various groups of older prawns, where to some extent external characters can be used in distinguishing for instance prawns in the transitional stages, and the ripening, berried and spent females. However, some of the younger year groups, particularly the large males, often overlap in size, and the separation of these is often done at an estimate according to the shape of the curve.

On the fishery cruises in Spitsbergen waters, plankton hauls in the sea surface have often been made mainly for the purpose of catching fish eggs. No vertical plankton hauls have been taken with the special intention of investigating the presence of larvae of the deep sea prawn. The present author has examined plankton material collected through a number of years in Spitsbergen waters without finding such larvae.

The temperatures in the water layers covering the prawn fields at Spitsbergen are widely different from those found in more southern regions where the *Pandalus borealis* is distributed. Investigations in Norwegian coastal waters have shown that only rarely the deep sea prawn is found in water with temperature below 3—4° C. Normally the prawns seem to prefer warmer water. On the prawn grounds at Spitsbergen we generally find in the summer season that the bottom layers have temperatures varying between 0° C and 3° C. However, negative temperatures are not infrequently met with. As an example of prawn catches in water with temperatures below 0° C we may cite some

hauls made in 1938. The duration of each haul of the prawn trawl is two hours (Table XXXVIII).

TABLE XXXVIII. Spitsbergen

Date 1938	Locality	Bottom temp.		Catch liters
		°C	S o/oo	
May 31	Karlskrona Deep	— 1,12	34,72	70
June 6	»	— 1,17	—	80
June 15	Rekesøyla	— 0,26	34,71	190
Sept. 7	Karlskrona Deep	— 0,56	34,67	14

In the sample from May 31st two prawns were found in which the eggs had recently hatched, and one individual had still some of the eyed eggs left. In the sample from September 7th 18 prawns were sorted out which had recently spawned and were egg-bearing. These findings seem to indicate that the cold water is no absolute hindrance for spawning and hatching of the eggs. Also the large trawl catches made in cold water show that the deep sea prawn easily can live and possibly thrive in such arctic surroundings. We may take it for granted that all these northern prawn grounds during a great part of the year are covered by cold water of Arctic origin. Although the bottom layers can show temperatures below 0° C at any time during the summer we generally find, however, in August and September a bottom temperature of about 2° C on the prawn grounds. For comparison it may be mentioned that on the prawn fields along the Norwegian coast bottom temperatures between 6 and 8° C are most common, while lower temperatures are found mainly in threshold fjords.

Spawning and Hatching.

On the various prawn grounds on the Norwegian coast the prawn generally spawns in October—November. At Spitsbergen ovigerous females are found at a considerably earlier date. Thus on July 8th 1925 7 prawns with freshly spawned eggs were found in a sample from Grön Fjord. In 1938 ovigerous females having just spawned were found in the Kross Fjord as early as July 2nd, and one ovigerous individual was found on July 11th on the prawn ground of Rekesøyla in the Foreland Sound. On July 7th 1946 two freshly berried prawns were caught on the prawn field in the Advent Fjord.

Through the samples taken in different years we are able to make a fairly satisfactory estimate of the duration of the spawning period.

The more numerous samples from 1936, 1938 and 1939 are particularly of great assistance in determining the main features of the spawning. Table XXXIX shows the number of ovigerous prawns in some selected samples and the percentage of occurrence after youngs and males have been removed.

TABLE XXXIX. Spitsbergen.

Date	Locality	Ovigerous females	
		No.	Per cent
July 8. 1946	Advent Fjord	2	5
July 16. 1940	Karlskrona Deep	3	43
July 11. 1938	Rekesøyla	1	3
July 19. 1946	Rekesøyla	2	3
July 21. 1939	Kongsfjord Deep	0	0
Aug. 2. 1939	—»—	12	18
Aug. 11. 1939	Karlskrona Deep	53	75
Aug. 19. 1936	Rekesøyla	33	65
Aug. 20. 1947	Rekesøyla	23	25
Aug. 30. 1939	Karlskrona Deep	52	82
Sept. 3. 1938	Krone Deep	98	65
Sept. 28. 1936	Bellsund Hole.....	32	97

The spawning can take place from early July till the end of September, i. e. a period of approximately 3 months. In Spitsbergen waters the spawning thus begins 3 months earlier than on the Norwegian Coast in general and is concluded two months earlier.

The prawns carry their eggs all winter, and hatching should normally be expected in early spring. The exact time for the commencement of hatching at Spitsbergen cannot be fixed with any accuracy as samples from early spring are lacking. It is not till late May that we are able to obtain any information on this point. On May 26th 1939 ovigerous females were caught with eyed eggs ready for hatching. In other specimens the eggs had partly hatched or there remained a varying number of eggs which in part were hatching and in part were dead or unfertilized. In other individuals all eggs had hatched, but the conspicuous setae of the female pleopods gave evidence that the first moulting after hatching had not taken place and the hatching thus should have occurred comparatively recently.

As an illustration of the progress in hatching we have in table XXXX listed some selected samples from two different localities in 1939. The percentages given refer to the sample after removal of youngs and males. The remaining prawns in the sample are sorted into groups containing

(1) ovigerous females with a varying number of eyed eggs, (2) females with setae but no eggs present, and (3) other prawns comprising females having moulted after hatching, prawns in transition stage or having finished the transition.

TABLE XXXX. Spitsbergen.

Date 1939	Locality	Eyed eggs present	Females not moulted	Others
May 26.	Kongsfjord Deep	34	15	51
May 31.	Rekesøyla	12	45	43
June 5.	»	0	26	74
June 22.	Kongs Fjord Deep ..	16	46	38
June 29.	—»— ..	0	20	80
July 7.	Poole Deep	0	0	95
July 21.	Kongs Fjord Deep ..	0	0	100

In late May we find still a large number of ovigerous prawns. Females with eyed eggs have been caught as late as June 22nd. In the locality of Rekesøyla the hatching seems to be more advanced than in the Kongs Fjord Deep. In Spitsbergen waters the hatching apparently is ended in the course of June.

From the material at disposal we cannot draw a complete picture of the general course of hatching in Spitsbergen waters. It is not improbable that the period of hatching may vary not only from one prawning ground to another, but also from one year to another. Thus in 1938 ovigerous prawns with partly hatched eggs were caught on May 31st, while later in the same summer no further hatching was observed.

We may assume that in Spitsbergen waters hatching of the larvae normally begins in late April, reaches a maximum in May and continues with decreasing intensity throughout June. In other words, hatching lasts for approximately two or $2^1/_2$ months, the same period as found in most localities on the Norwegian coast. However, at Spitsbergen the hatching occurs two months later in the year.

The deep sea prawn in Spitsbergen waters thus has an ovigerous period of about 9 months, reckoned from the end of spawning in late September till end of hatching in late June. The ovigerous period at Spitsbergen is thus about 4 months longer than what is the case in most prawn fields, for instance i Southern Norway. For the determination of the age of the Spitsbergen prawn July 1st may be considered the birth date.

In West Greenland waters Stephensen (1935) found berried females

in early September. The ovigerous period in that area has by HJORT and RUUD been estimated to last for 6—8 months, the eggs hatching in April—May. If such is the case there is a very good agreement in regard to the spawning and hatching of the deep sea prawn in these two widely separated Arctic localities.

The Youngs, Males and Transition Animals.

As mentioned above the ovigerous period of the deep sea prawn at Spitsbergen lasted about 4 months longer than in Southern Norway, and the hatching was completed about two months later in the year. On the basis of these findings we may presume that also the pelagic development of the larvae will take longer time in northern waters. This opinion is also expressed by HJORT and RUUD in reference to the material collected in Greenland waters.

As already stated we have no material of pelagic prawn larvae from Spitsbergen and we are therefore compelled to draw our conclusions in regard to the duration of the pelagic existence of the larvae on the basis of the smallest bottom stages caught in the prawn trawl. Young prawns measuring 32—48 mm have been caught in the prawn trawl on several occasions. The catch of small youngs was particularly rich in a haul made in the Kross Fjord on July 2nd 1938. The size distribution of the prawns in a sample of 522 specimens from that locality is shown on the extreme left in fig. 33 B. The figure also contains measurement series from other catches where youngs and males are illustrated by white, the transitionals by shaded and females by black columns. The mean size of the youngest groups is shown in table XXXXI.

TABLE XXXXI. I-group. Spitsbergen.

Date	Locality	No. of ind.	Mean size of I-group mm
June 28. 1938	Krone Deep	10	39,75
July 2. »	Kross Fjord	60	37,63
July 16. 1940	Karlskrona Deep	13	39,49
July 19. 1946	Rekesøyla	24	41,98
Aug. 11. 1939	Karlskrona Deep	5	41,34
Total mean	.....	112	39,11

As illustrated in the table the youngs show hardly any growth from one month to another, and the variations in size may very well be due to the small representation of the group in the samples. Now the question arises of how old these small prawns can be.

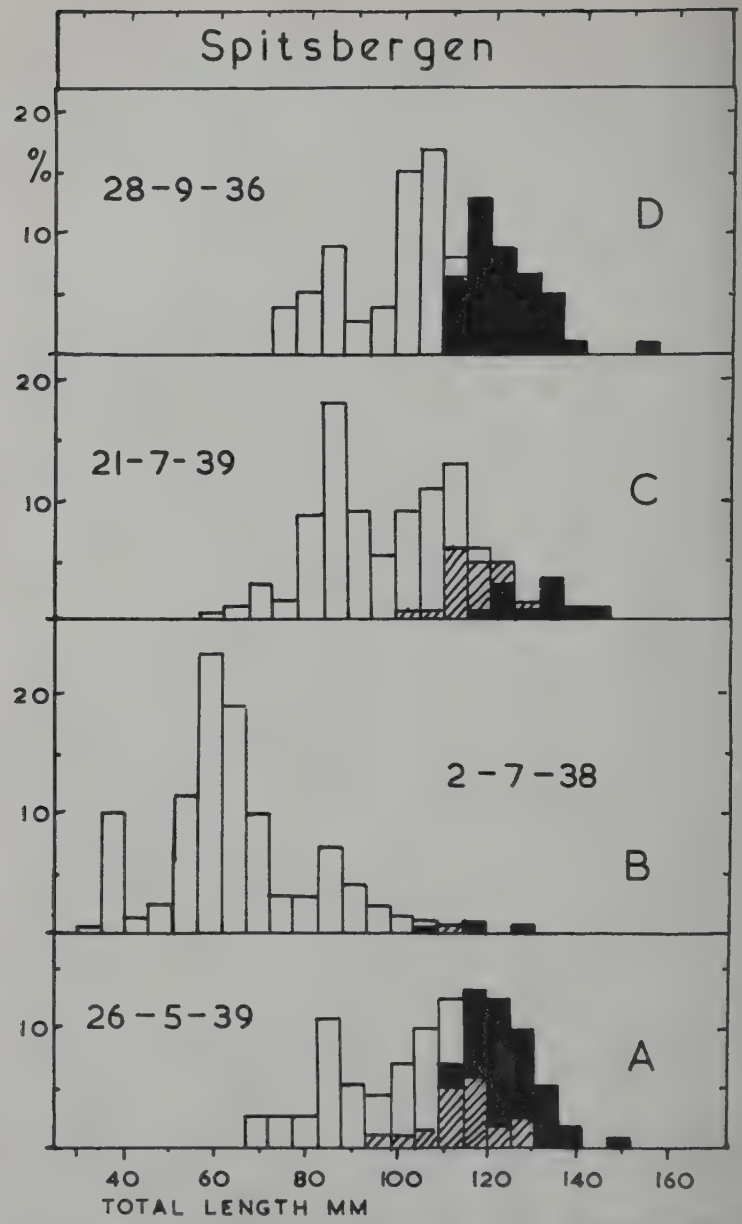

Fig. 33. Size Distribution of Prawns in Selected Samples from Spitsbergen. White Males. Shaded: Transitionals. Black: Females.

We have seen that the prawn larvae mainly hatch in May and June when the pelagic existence commences. If the pelagic life lasted for about 3 months as in Southern Norway, we should have expected to find the first bottom stages measuring about 17 mm some time in September, and youngs with a mean size of 39 mm still later in the year.

In the Brands Fjord young prawns 37,10 and 42,14 mm in length, were respectively 5½ and 6½ months old. In the Mist Fjord in Northern Norway prawns with a mean size of 41,66 mm were approximately 9 months old.

Based on the supposition that the pelagic life, on account of the cold surroundings in Spitsbergen waters, is prolonged on the same scale as the ovigerous period, the larvae should not settle to the bottom till December—January. In any case it seems improbable that the group of small prawns found in the trawl catches in the last days of June and early July should be hatched in May and June of the same year. These young prawns must have been hatched during the preceding summer and thus at the date of capture be about one year old.

With this group of youngs as a starting point we may now consider the other groups present in the samples. As indicated in fig. 33 B the next size group of prawns is concentrated around a length of 60—70 mm. In table XXXXII are listed the samples in which the size group is more easily segregated.

By July 1st these prawns have completed their second year of life and may be referred to as year group II, exhibiting a comparatively great variation in size distribution in the various samples. The cause of this may be error in sampling or it may be ascribed to different growth rates in the various localities.

TABLE XXXXII. II-group. Spitsbergen

Date	Locality	No. of ind.	Mean size of II-group mm
May 31. 1938	Karlskrona Deep	18	62,70
June 28. »	Krone Deep	84	62,70
July 2. »	Kross Fjord	353	63,07
» 7. 1939	Poole Deep	32	69,22
» 8. 1946	Advent Fjord	28	68,16
» 16. 1940	Karlskrona Deep	20	62,01
» 19. 1946	Rekesøyla	101	72,24
» 21. 1939	Kongs Fjord Deep	9	69,15
Aug. 20. 1947	Rekesøyla	129	72,77
Sept. 3. 1938	Krone Deep	56	68,00
All localities		830	65,29

We notice for instance that the mean lengths of the II-group in the Rekesøyla are greater than in any of the other localities. It is difficult to point to any definite growth from month to month in such a mixed material. The mean lengths for all localities are: May 62,70 mm, June 62,70 mm, July 65,35 mm, August 72,77 mm and September 68.00 mm. The mean length of the II-group computed from all the samples listed is 65,29 mm. The average increase in length from the preceding summer is 26,18 mm. The size of the two year old prawns in Spitsbergen waters corresponds to that attained on the Torungen ground in Southern Norway in 11 months, and to that on the Mist Fjord ground in Northern Norway in about 22 months.

The prawns belonging to the II-group vary in size between 48 and 80 mm, the majority being in the 64 mm group. In a sample from July 19th 1946 an examination of the sexual organs revealed that some of the largest individuals of the II-group were sexually mature males. Of 44 individuals in the 74 mm group 11 per cent contained sperm in vasa deferentia, and among the largest individuals, 80 mm in length, 50 per cent were sexually mature males.

Among the 101 individuals belonging to the II-group 14 per cent were able to spawn. The mean size of the II-group in this sample was 72,24 mm and thus greater than in other samples. At Spitsbergen, as in more southern waters, there is apparantly a connection between the size of the prawn and the ability to produce sperm. In such case we must presume that generally only an insignificant number of the Spitsbergen prawn becomes sexually mature males when two years of age.

In fig. 33 we find the next size group to be considered centered around the 80—90 mm marks. This size group is clearly defined in the majority of the samples. In table XXXXIII are listed the computed mean lengths for this group as found in the various localities.

By July 1st this group of prawns has completed its third year of life and thus constitute the III-group of prawns. We find a comparatively great variation in the mean lengths in the different samples, and as was the case with the II-group it is difficult to point to any definite growth from one month to another. The monthly mean lengths for all localities are: May 87,03 mm, June 89,94 mm, July 86,50 mm, August 88,03 mm, and September 82,15 mm. From table 26 it is evident that the mean lengths of the III-group from the Rekesøyla are slightly larger than in other localities.

The 3 year old prawns have a size distribution between 74 and 100 mm, the mean length for all localities being 87,45 mm. This is the same size as the prawns in Southern Norway (Torungen ground) attain in about 18 months, and the Mist Fjord prawns in about 30

months. The average increment of growth from the preceding summer of the Spitsbergen prawn is 22,16 mm. An examination of the sexual organs of the III-group in a sample from Rekesøyla on July 19th 1946 proved that the prawns of this size group were sexually mature males, having well developed vasa deferentia partly or completely filled with sperm. The 1946-sample has not been included in table XXXXIII as the grouping of the males was not clearly defined.

TABLE XXXXIII. III-group. Spitsbergen.

Date	Locality	No. of ind.	Mean size of III-group mm
May 26. 1939	Kongs Fjord Deep	24	85,91
» 31. »	Rekesøyla	23	88,25
June 5. »	»	24	88,09
» 22. »	Kongsfjord Deep	12	86,13
» 29. »	—»—	27	93,24
July 1. »	Rekesøyla	15	88,67
» 7. »	Poole Deep	48	88,56
» 8. 1925	Grøn Fjord	90	84,75
» 11. 1938	Rekesøyla	29	90,10
» 21. 1939	Kongs Fjord Deep	65	85,38
Aug. 2. »	»	16	83,79
» 11. »	Karlskrona Deep	31	86,50
» 20. 1947	Rekesøyla	71	92,01
» 23. 1937	»	23	89,84
» 26. 1938	Krone Deep	34	85,44
» 30. 1939	Karlskrona Deep	27	86,76
Sept. 28. 1936	Bellsund Hole	16	82,15
All localities		575	87,45

In Southern Norway the prawns on the Torungen ground attain male maturity mostly when 18 months old, and the same is the case in the Vigra Fjord and on other grounds. In the Mist Fjord the prawns were sexually mature males when 30 months old. As mentioned above the size of the prawns at this age in the Mist Fjord is the same as that of the 36 months old Spitsbergen prawns.

Thus the deep sea prawn at Spitsbergen and the prawn on the Norwegian coast obviously mature as males at approximately the same size. But the time elapsed before reaching this stage can vary greatly. On the Norwegian coast it takes generally 18 months, in a cold threshold fjord it may take 30 months, and in Spitsbergen waters at least 36 months.

In the measurement series illustrated in fig. 33 we find still another

group of male prawns concentrated near the 100—110 mm marks. The mean lengths of this group (age group IV) in the various localities are listed in table XXXXIV.

TABLE XXXXIV. IV-group. Spitsbergen.

Date	Locality	No. of ind.	Mean size of IV-group mm
May 26. 1939	Kongs Fjord Deep	24	104,89
» 31. »	Rekesøyla	15	107,06
June 5. »	»	27	104,25
» 29. »	Kongs Fjord Deep	24	107,11
July 1. »	Rekesøyla	26	106,80
» 8. 1925	Grøn Fjord	105	102,29
» 11. 1938	Rekesøyla	75	103,03
» 21. 1939	Kongs Fjord Deep	48	104,21
Aug. 2. »	—»—	18	103,93
» 11. »	Karlskrona Deep	36	104,94
» 20. 1947	Rekesøyla	41	106,80
» 23. 1937	»	32	102,50
» 30. 1939	Karlskrona Deep	52	105,10
Sept. 28. 1936	Bellsund Hole	29	102,87
All localities		552	104,25

From the table it is evident that there is no distinct growth generally for the whole area during the season. This is also the case when the mean for each separate month is calculated. The mean length in May is 105,74 mm, June 103,58 mm, August 104,89 mm and September 102,87 mm. This apparent lack of growth indicated by the figures may be due to the mixed composition of the material. The reason for lack of growth can also be that a number of the largest males transforms into females in the course of the summer, with the result that the mean size of the remaining males will decrease or remain the same. As mentioned in earlier shapters this is the usual effect if the male group splits in two fractions.

The IV-group of prawns has a size distribution between 95 and 117 mm, and the total mean size is 104,25 mm. The increment in growth from the preceding summer is 16,8 mm. All the prawns of the IV-group have in late summer mature testes and function as active males. If the interpretation of the life history of the deep sea prawn thus far is correct, we find that probably the whole brood or the majority of prawns at Spitsbergen function as active males for two years in succession.

Hjort and Ruud mention in their publication on the prawn that in Southern Norway the phenomenon of prawns functioning as active males

for two years is not unknown. The descriptions of the life history of various prawn populations on the Norwegian coast, as given in preceding chapters, show that it is quite an ordinary thing that a smaller or larger part of a year class of prawns function twice as males. In most localities we find males 18 and 30 months old, while for instance the prawns from a threshold fjord (Mist Fjord) were active males when 30 and 42 months old. The prawns at Spitsbergen are functioning actively as males at least twice, i. e. when 38 and 50 months of age.

The Transition Stages and The First Time Female Spawners.

On the prawn grounds on the Norwegian coast we generally find the prawns in the transition stages already a few months after spawning, i. e. in January and throughout the spring. Usually these prawns have completed their transition by July when they have attained purely female characters. However, in Spitsbergen waters the transformation of males into females takes place over a much longer period. Table XXXXV shows the percentages of transition animals, maturing females and berried females at various dates in catches from a single locality (Rekesøyla 1939).

TABLE XXXXV. Spitsbergen.

Date 1939	No. of ind.	Transition animals	Ripening females	Berried females	Other females %
May 31	67	16	16	—	68
June 5	53	27	11	—	62
July 1	66	52	36	—	12
» 7	66	73	12	—	15
Aug. 13	81	15	35	47	3
» 30	72	—	26	74	—

In the material from Spitsbergen we have no samples before the end of May, and at this date we find the transition animals in stage B, C and D. It is remarkable that already in May the ripening of the ovaries in the transition animals is so far advanced that they have visible "roe in the head". The presence of all these transition stages also indicates that the process of transformation must have been going on for some time. The numerical strength of the transition stages shows an increasing tendency towards July. Later on the relative number of transitionals decreases as they pass into the category of ripening females or become ovigerous. At the end of August all transition animals have disappeared

in samples from Rekesøyla, while instead the ovigerous prawns are dominating. In other localities, as for instance the Krone Deep, transition animals in stage C and D are still found on September 3rd 1938. It is not inconceiveable that the process of transition from males to females goes on throughout the whole year in these Arctic regions.

The 4 year old prawns functioning as males for the second time had a mean length of 104,25 mm. The transformation of these males apparently begins the following winter. The moulting into the first transition stage (B) has at least taken place before the end of May. Thus in a sample from the Kongs Fjord Deep taken on May 26th 1939 only 3 out of 22 transition animals were in stage B, while 8 were in stage C and 11 in stage D. We may concede that the individuals in the transition stages and the maturing animals are largely prawns which will complete their 5th year of life by July 1st. The size and sexual development of these prawns belonging to the V-group are shown in table XXXXVI.

TABLE XXXXVI. V-group. Spitsbergen.

Date 1939	Locality	Age months	No. of ind.	Transition stages		Maturing females		Ovigerous females		Tota mea size mm
				per cent	size mm	per cent	size mm	per cent	size mm	
May 26.	Kongs Fjord Deep	59	30	73	114,43	27	126,51	—	—	117,7
» 31.	Rekesøyla	59	21	52	116,60	48	127,20	—	—	121,6
June 5.	»	59	18	78	116,60	22	119,25	—	—	117,1
» 22.	Kongs Fjord Deep	60	17	53	116,60	47	121,21	—		118,7
» 29.	—»—	60	68	62	115,06	38	122,11	—	—	117,6
July 1.	Rekesøyla	60	58	59	116,60	41	123,44	—	—	119,4
» 7.	Poole Deep	60,5	56	86	116,81	14	127,00	—	—	118,3
» 21.	Kongs Fjord Deep	60,5	35	66	114,27	34	128,43			119,4
Aug. 2.	—»—	61	48	33	114,59	36	124,07	31	121,53	120,2
» 11.	Karlskrona Deep	61,5	66	5	107,75	15	111,30	80	114,59	113,7
» 13.	Rekesøyla	61,5	81	18	114,85	37	125,24	45	119,09	120,2
» 30.	»	62	70	—	—	27	130,54	73	119,78	123,0
» 30.	Karlskrona Deep	62	58	3	113,95	7	119,25	90	115,65	115,8
					115,49		124,02		117,29	118,7

As is seen from the table the size of the transition animals is quite uniform all through the summer. In the different samples the mean size varies between 108 and 119 mm. Nearly all transition animals have visible "roe in the head" early in the summer and we can expect that they will spawn for the first time as females later in the season. A few individuals, however, bear no sign that they will mature during the same summer in which the transition is completed. In order to ascertain

more accurately the size of the prawns becoming ovigerous for the first time, a closer examination of the external characters of the ovigerous prawns was made. This examination disclosed the fact that many individuals had not completed their transformation into females before spawning. These incomplete females were in the transition stages C and D, and thus still retained rudimentary characters from their male existence. In two samples from Karlskrona Deep taken on August 11th and August 30th 1939 containing 105 berried females, altogether 33 such ovigerous transition animals were found, and these can be classed at once as first time spawners. The size varied between 100 and 117 mm and the mean length was 110,01 mm.

We must, however, presume that the majority of the prawns complete their transformation before actually spawning. In table XXXXVI are also listed the mean lengths of the maturing females found in the samples. As might be expected the lengths of these latter lie somewhat above that of the transition animals, the mean size in the different samples varying between 111 and 130 mm. From the beginning of August a steadily increasing part of the prawns become ovigerous, and at the end of that month 90 per cent of the females are egg-bearing. The size of the ovigerous prawns which according to their external characters and their size distribution may be considered as first time female spawners, varies between 116 and 122 mm in the different samples.

As was the case with the younger prawns at Spitsbergen we cannot demonstrate a decided growth from month to month among the transitionals, the maturing, and the ovigerous prawns respectively. But we are able to indicate the average increment from the one stage to the other. The mean size of 239 transition animals caught during the whole summer 1939 is 115,49 mm, that of 180 maturing prawns 124,02 mm and that of 207 ovigerous prawns 117,29 mm. The high figure for the maturing females may be due to error in sampling or to the fact that older and larger prawns maturing for a second time have been included. The mean size of all these categories of prawns during May—August is 118,72 mm which may be considered the mean size of the prawns completing their fourth year of life during summer and which from July 1st enter the V-group. The increment of growth from last summer is 14,47 mm.

As has been shown in earlier chapters the prawns on the various grounds on the Norwegian coast generally become ovigerous when approaching a size of 120 mm. It is significant that in spite of the great difference in growth rate the prawns in Norwegian waters and those at Spitsbergen are approximately of equal size when reaching sexual maturity as females and becoming ovigerous for the first time.

However, at Spitsbergen all or most of the prawns at this stage are 5 years old while the prawns in the more southern localities are mostly 2½ or 3½ years of age. Another prawn field in Norway which has shown a deviating course of development is the Mist Fjord. In that locality the prawns were probably 4½ years of age when becoming ovigerous for the first time at a size of 114 mm. This is only slightly below the size of the 5 year old Spitsbergen prawns.

The Older Prawns.

We can take it for granted that the prawns do not moult while egg-bearing, and the growth of the ovigerous females is thus stopped from the moment of spawning till the time of hatching, i. e. a period of about 9 months.

For this reason we can expect already beforehand that the growth of the Spitsbergen prawn will be rather small in its sixth year.

The first-time spawners which became ovigerous in early autumn are present in the catches made in May—June of the following year. The eggs are by now hatching, or the hatching is concluded. Individuals which have not moulted after the hatching are quite easily sorted out in the samples. In the following these prawns are referred to as "spent females" although this designation is not quite correct. In table XXXXVII is shown the size of the spent females which according to their grouping should mainly comprise the first time spawners. The mean size of the individuals sorted out as recently spent females is calculated at 121,53 mm, only 2,81 mm above the estimated size of the spawning females of the preceeding autumn.

While the transition animals had "roe in the head" already in May the majority of spent females show no sign of maturing again. Only comparatively few of the spent females have visible signs of developing roe during or soon after hatching of the old eggs. Of all individuals sorted out as recently spent females in the period May 26th—July 7th 1939 82 per cent show no signs of maturing again, and they will in all probablity not be able to spawn again within the same summer in which the eggs are hatched.

In the samples we also find a number of non-maturing individuals among the females which bear no sign that their eggs have recently hatched. Such individuals can be found quite commonly throughout the summer and thus also at a time when the transitionals and females of the V-group have become ovigerous. Table XXXXVII contains a column where the number and size of these non-maturing females are listed. Their mean length agrees very well with that of the recently spent females.

These prawns which show no sign of maturing even late in summer are presumeably identical with the recently spent and mostly non-maturing females listed in the first column of the table. They are in case females which have moulted after the hatching of the eggs. The mean lengths of the recently spent and non-maturing females are given in the last column of table XXXXVII.

TABLE XXXXVII. VI-group. Spitsbergen.

Date 1939	Locality	Recently »spent females«		Non-maturing females		Total mean size mm
		no. of ind.	mean size mm	No. of ind.	mean size mm	
May 26.	Kongs Fjord Deep	28	122,86	0	—	122,86
» 31.	Rekesøyla	36	121,90	7	118,88	121,42
June 5.	»	11	117,08	19	121,64	119,94
» 22.	Kongs Fjord Deep	41	120,47	9	131,33	122,43
» 29.	—»—	20	123,76	27	123,86	123,81
July 1.	Rekesøyla	—	—	8	119,89	119,89
» 7.	Poole Deep	3	121,90	7	122,64	122,43
» 21.	Kongs Fjord Deep	—	—	6	124,55	124,55
Aug. 2.	—»—	—	—	18	121,90	121,90
» 11.	Karlskrona Deep ..	—	—	5	117,66	117,66
» 13.	Rekesøyla	—	—	3	123,65	123,65
» 30.	—»—	—	—	5	120,84	120,84
			121,53		122,75	122,06

The lengths of the prawns are quite uniform in the various localities throughout the summer, and there is no definite growth to be observed after the hatching of the eggs is concluded. Thus the mean size between May 26th and July 1st is 122,11 mm, and between July 1st and August 30th 121,74 mm. The mean size for the whole summer in all localities is 122,06 mm.

These prawns measuring 122.06 mm should by July 1st have completed their sixth year of life and thus constitute the VI-group. The increase in size from last summer is, as anticipated, very small, on an average only 3,34 mm. The most significant point is, however, that *the majority of the females having hatched their youngs in spring do not mature again within the same season, but enter a period of sexual rest.* How long this period of rest lasts is difficult to ascertain with any degree of certainty. The material contains only very few large prawns which point out the subsequent growth and development.

In the combined samples from the Kongs Fjord Deep taken on June 22nd and 29th we find a separate group of 41 large prawns with a mean

size of 142,04 mm. Of these 20 per cent are maturing females (mean size 143,74 mm), 41 per cent are non-maturing (142,46 mm) and 39 per cent have been ovigerous during the last winter (140,77 mm). Another sample from the Krone Deep contains a group of 30 large prawns with a mean size of 137,8 mm. Of these 10 per cent are non-maturing (146,65 mm) and 90 per cent have recently spawned (136,95 mm). The total mean size of the large prawns in both samples is 140,24 mm.

This group of large prawns probably contains individuals which are 7 years old by July 1st, but possibly intermixed with still older prawns. Presumeably the ovaries of some of the prawns which have had a period of sexual rest mature again during the spring and summer. At the end of the summer when 7 years old they should thus become ovigerous for the second time. Other large prawns found in the spring have perhaps been ovigerous two years in succession, while some individuals do not even mature again when 7 years of age.

The scarcity of large prawns in the material makes a correct interpretation imposible. The increase in size of the prawns from last summer is on the average 18,18 mm. This figure indicates that the growth of the prawns between the sixth and seventh year of age has been larger than in the preceding year. This seems quite natural when taking into account that between the sixth and seventh year of age a number of the prawns have had a period of sexual rest and thus a greater number of moultings with a subsequent faster growth than in preceding year.

On the Prawn from Jan Mayen.

From Jan Mayen waters we have one sample of 639 individuals collected during a cruise with the research vessel "G. O. Sars" on August 1st 1950. A haul with the prawn trawl was made 4 miles west of the Hvalross Gatt in a depth of 150- -210 meters. From a cursory glance at the sample it was evident that the prawns were exceedingly large and of exellent quality. The measurement series confirmed this first impression.

In the sample 87 per cent of the females are ovigerous, and spawning has thus occurred in the course of July, i. e. earlier than in any locality hitherto investigated. The hatching of the eggs has presumeably taken place earlier in the summer, probably before June 1st. The ovigerous period is estimated to have at least the same duration as in Spitsbergen waters.

The size distribution of the different age groups is shown in fig. 34. The group containing the smallest prawns has a mean size of 49,45 mm. These prawns must have completed their first year of life earlier in the summer and belong to the I-group. If June 1st is fixed as the birth

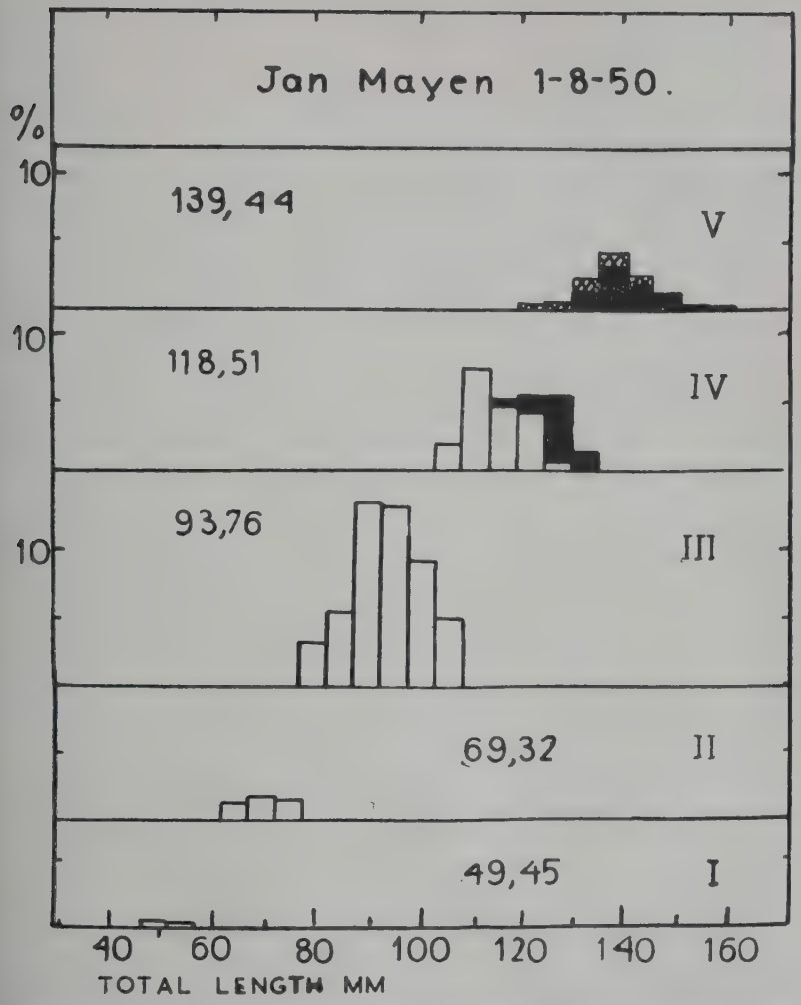

Fig. 34. The Size Distribution and Sex Composition of Prawns in a Sample from Jan Mayen. White: Youngs and Males. Black: Mature Females. Shaded: Non-maturing Spent Females

date the age will be 14 months. The II-group has a size of 69,32 mm and the III-group 93,76 mm. The 3 year old prawns are active males. A year later a division has taken place with the result that 71 per cent of the IV-group are active males for the second time in life at a size of 115,12 mm, while 29 per cent of the larger individuals are ovigerous

females with a mean length of 126,67 mm. The total mean size of the IV-group is 118,51 mm.

When 5 year old all prawns have transformed into females. There are two groups of them, one being ovigerous for the first time, having attained a mean size of 140,93 mm, the other consisting of non-maturing females measuring on an average 133,72 mm. These latter are probably the same individualswhich matured as females when 4 years old and which have been egg-bearing during the last winter. They are in case spent prawns which do not mature again immediately after the hatching of the eggs, but enter a period of sexual rest. This is a development which was demonstrated also in the Spitsbergen material. The total mean size of the V-group is 139,44 mm.

The most impressing feature of the Jan Mayen prawns is the large size of the sexually mature prawns. The males of the IV-group are for instance 115,12 mm. On other prawn fields such large individuals usually occur only among the females. Also the females in the Jan Mayen field are exceptionally large.

Information on the hydrographic conditions on the Jan Mayen Bank has among others been given by Thor Iversen (1936). The temperature conditions are apparantly very similar to those found at Spitsbergen. A station worked on August 9th 1930 in about the same locality where the prawns were caught showed a bottom temperature of 0,28 ° C and a salinity of 34,10 ‰ at 180 meters. Closer to the shore, at 65 meters, the bottom temperatur was 2,17 ° C and the salinity 34,88 ‰; and further out between 200 and 400 meters the bottom temperature decreased from 0,40 to — 0,29 ° C, the salinities remaining about the same. On September 3rd 1933 a hydrographic station in the same vicinity showed a bottom temperature of 0,49 ° C and a salinity of 34,91 ‰ in 153 meters.

Remarks on the Arctic Prawn Populations.

The growth curves of the deep sea prawn from Spitsbergen and Jan Mayen are shown in Fig. 35. For comparison are also drawn the curves from some localities on the Norwegian coast. With reference to the curve the growth and development of the Spitsbergen prawn can be summarized as follows:

1 year old,	length	39,11 mm	Immature youngs
2	—»—	65,29 »	—»—
3	—»—	87,45 »	Mature males
4	—»—	104,25 »	—»—
5	—»—	118,72 »	Transition to spawning females
6	—»—	122,06 »	Spent females, many not rematuring
7	—»—	140,24 »	Females rematuring for 2nd spawning, also spent and non-maturing individuals.

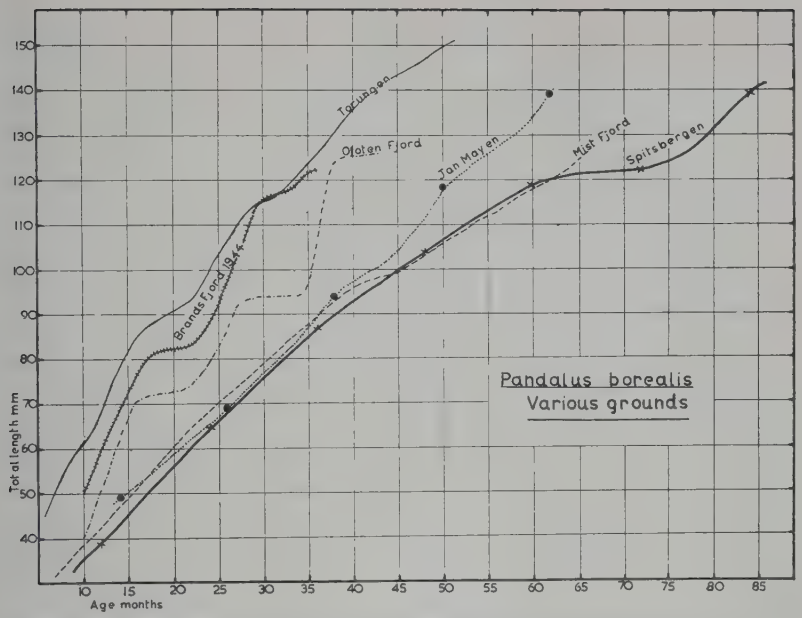

Fig. 35. The Growth Curves of the Prawns from Spitsbergen and Jan Mayen. For Comparison Growth Curves of Some Prawn Populations on the Norwegian Coast.

In the Jan Mayen material the prawn showed the following life history:

14 months old, length	49,45 mm	Immature youngs
26	—»—	69,32 »	—»—
38	—»—	93,76 »	Mature males
50	—»—	118,51 »	71 % mature males, 29 % mature females.
62	—»—	139,49 »	Mature females and non-maturing »spents«.

The rate of growth and the sexual development of the prawns in the Arctic areas of Spitsbergen and Jan Mayen are not identical, but show even great differences. The examination of the material shows that in the Jan Mayen area the prawn grows faster and matures earlier than the prawn in Spitsbergen waters. Whether this is a regular difference in behaviour or just a feature shown in that particular year is, however, impossible to state from the scarse material.

The history of maturing of the older prawn at Spitsbergen has proved to be rather complicated. But also among the younger individuals we can find instances which indicate variations in the general scheme of

development outlined above. Thus, for instance, male prawns measuring 127 mm have been found, a size which is to be expected among the old female prawns. Such large males might be specimens having had an extraordinary rapid growth, but it is also possible that individual prawns can function as males for more than the normal two years.

A sample from May 31st 1938 contained a transition animal, stage B, measuring 85 mm. At this size the prawn should normally be a male, but it carried a parasite (*Phryxus abdominalis*) which presumeably had been the cause of the premature transformation of the endopodite of the first pair of pleopods. In contrast to other transition animals this one did not have ripening ovaries.

In the Spitsbergen material we have found prawns of 95 mm with well developed eggs beneath the carapace, and similarly ovigerous and spent prawns down to a size of 100 mm. Individuals of this size should normally belong to the IV-group of prawns functioning as males for the second time. In the prawns from Jan Mayen we have seen that the larger individuals of the group of 4 year old prawns are able to change into females while the smaller individuals of the same group maintain their male characters. It is not improbable that a similar development occasionally takes place also at Spitsbergen. As seen in fig. 33 the size of the largest males to some degree overlaps that of the transition animals. Judging by the size distribution, some of the largest males may perhaps change into females already in their fourth year as was the case among the prawns from Jan Mayen.

In the study of the prawns from different prawn grounds in Norway and likewise at Jan Mayen it appears that if any considerable number of male prawns are transformed into females, this has a noticeable depreciating effect on the numerical strength of the remaining males during the following season. If, in a similar manner, a great number of the 3 year old males in Spitsbergen waters should change sex and become spawning females the next season, we should expect a decrease in the relative numerical strength of the male group between 3 and 4 years of age. As seen in fig. 33 the group of 4 year old males is quite strong in the catches from September 28th 1936, and on this occasion probably no division of the year class has taken place. In the catches from May 26th and July 21st 1939 the numerical strength of the 4 year old males is relatively small. Possibly in the latter year the group should also include some individuals which have changed their sex between their third and fourth year.

According to our experience in more southern localities the rate of growth and development of the prawn can vary from year to year and from one locality to another, a variation apparently due to changes in

the surroundings and the local conditions. It is not improbable that yearly variations in the temperature, salinity and oxygen content of the bottom water may cause similar variations in the rate of growth and sexual development both in Spitsbergen and Jan Mayen waters.

Some Notes on Prawn Populations in Various Localities.

Vestlandet District.

From the district of Vestlandet (West Coast) we have at our disposal scattered prawn samples collected in the region around Bergen (Hordaland), the outer part of the Sogne Fjord and in some branches of the Sogne Fjord proper (see chart fig. 2).

From the Hordaland region we hawe prawn samples from the following grounds:

Matre Fjord, 60° 52′ N. lat. 5° 30′ E. long., one sample from September 23rd 1944 containing 158 prawns.

Radøy Fjord, 60° 34,6′ N. lat. 5° 11,3′ E. long., depth 210 m. One sample from September 20th 1941 containing 128 prawns.

Solsvik, 60° 23,6′ N. lat. 4° 57,6′ E. long., depth 150 m. One sample from August 8th 1945 containing 619 prawns.

The rate of growth and the sexual development vary somewhat from one locality to another (fig. 36). When approximately 1½ years of age, the prawns in all localities are supposedly active males after having reached the following mean lengths:

Radøy Fjord 89,89 mm, Solsvik 74,25 mm and Matre Fjord 72,56 mm. When approximately 2½ years of age the year group in all localities has split into males and females according to the scheme shown in table XXXXVIII.

TABLE XXXXVIII. Vestlandet.

Locality	Males		Females		Total mean size mm
	per cent	size mm	per cent	size mm	
Radøy Fjord	56	116,18	44	123,01	111,20
Solsvik	48	98,26	52	108,97	103,83
Matre Fjord	92	92,96	8	107,33	94,13

The lowest rate of growth is found in the Matre Fjord combined with a low number of maturing females. When approximately 3½ years of age all the prawns in the different localities have transformed into females and have attained the following mean lengths: The Radøy Fjord 146,02 mm, Solsvik 123,30 mm and the Matre Fjord 129,85 mm.

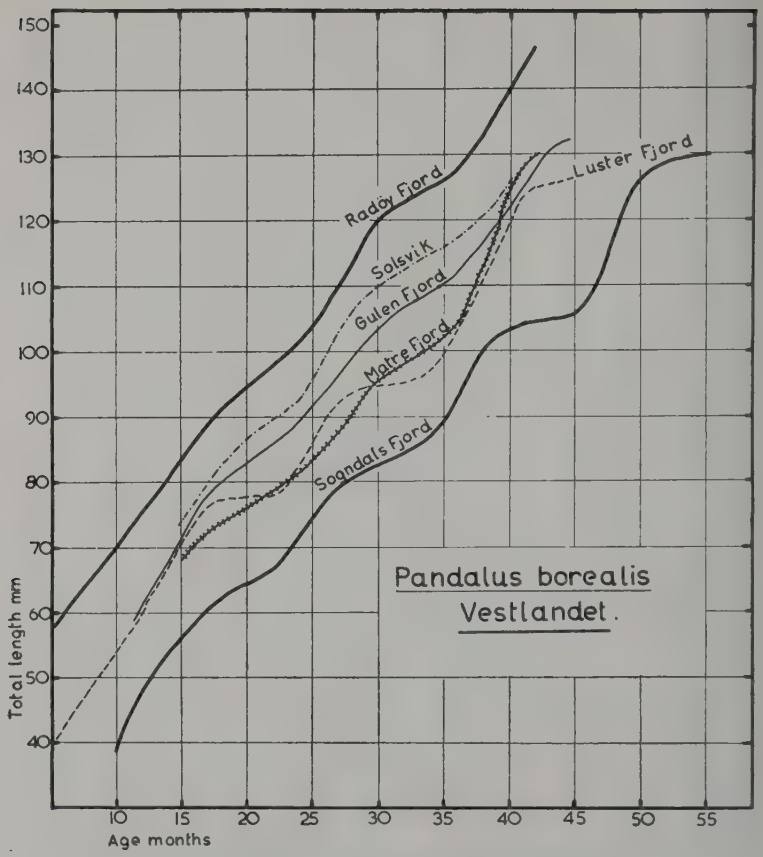

Fig. 36. The Growth Curves of the Prawns from Different Localities on the West Coast of Norway.

From the region of Gulen in the outer part of Sogn we have samples from the following prawn grounds:

Gulen Fjord, 60° 57,7′ N. lat. 5° 5,4′ E. long., depth 180 m. Two samples from respectively September 22nd 1941 and April 11th 1945 containing 135 and 186 prawns.

Nyhammersund, 61° 00′ N. lat. 5° 1,8′ E. long., depth 140—150 m. Two samples from respectively March 7th and April 28th 1945 containing 745 and 327 prawns.

Svabergosen, 60° 58′ N. lat. 5° 9′ E. long., depth 180—220 m. One sample from April 28th 1945 containing 409 prawns.

North Gulen Fjord, 60° 58,7′ N. lat. 5° 5,4 E. long., depth 180 m. One sample from April 28th 1945 containing 540 prawns.

Mjømenosen, 60° 56,5′ N. lat. 4° 55′ E. long., depth 200 m. One sample from April 30th 1945 containing 558 prawns.

Rososen, 60° 58,6′ N. lat. 4° 56′ E. long., depth 132 m. One sample from April 30th containing 780 prawns.

Undeland Sound, 60° 55,7′ N. lat. 4° 57,6′ E. long., depth 125 m. One sample from April 30th 1945 containing 873 prawns.

Hage Fjord, 61° 11,3′ N. lat. 4° 52,4′ E. long., depth 130 m. One sample from April 28th 1945 containing 491 prawns.

On all these grounds the growth and maturing seem to be much the same. In the Gulen Fjord the spawning probably takes place in October—November. The hatching in all localities is over by the end of the following April. When one year old the mean size of the prawns varies between 52,36 and 62,86 mm on the different grounds. Half a year later, upon the commencement of spawning, the prawns from the Gulen Fjord measure on an average 78,02 mm. According to their size distribution all the prawns from that locality should be active males at that age. A similar development is also to be expected on the other grounds in this area.

At the end of April the following year, when the prawns are approximately two years old a division of the age group has occurred and we find a composition in the different localities as shown in table XXXXIX.

TABLE XXXXIX. Age appr. 2 years. Vestlandet.

Locality	Males		Transitionals		Total mean size mm
	per cent	size mm	per cent	size mm	
Rososen	51	67,63	49	90,79	83,00
Nyhammersund	54	77,59	46	94,98	85,54
Undeland Sound	40	78,07	60	92,96	86,97
Mjømenosen	41	79,98	59	95,35	89,04
Gulen Fjord	67	84,54	33	100,65	89,89
Svabergosen	59	83,05	41	101,07	90,47
Hagefjord	54	90,84	46	99,48	94,76

On these grounds at least between 33 and 60 per cent of the prawns will mature as females when 2½ years of age, while 40—67 per cent will spawn as males for the second time. Towards the end of September the second-time male spawners in the Gulen Fjord measure 97,52

mm, and the female fraction 109,87 mm, the total mean size of the age group being 102,71 mm. They will still increase somewhat in size before spawning sets in a month later.

It is difficult from the scattered samples to trace the further growth and development with any degree of accuracy. At the end of April, when 3 years of age, we find a group of spent prawns probably intermixed with individuals having recently completed their transformation from males to females. In the different localities the mean size of the 3 year old prawns varies between 105,36 and 118,99 mm.

In the *region of Sogne Fjord proper* samples have been collected from the following localities:

Luster Fjord, 61° 26,3′ N. lat. 70° 28,3′ E. long. Depth 130 m. Four samples containing 309, 450, 1209 and 210 prawns collected on July 4th and October 17th 1944 and on February 21st and July 3rd 1945.

Vetle Fjord, 61° 15,5′ N. lat. 6° 33,3′ E. long. Depth 250—300 m. Three samples containing 538, 878 and 416 prawns collected respectively on July 21st 1944, February 19th, and on July 14th 1945.

Sogndals Fjord, 61° 12,2′ N. lat. 7° 8′ E. long. Depth 200—300 m. Five samples containing 417, 417, 764, 1236 and 377 prawns, collected respectively on July 8th and October 20th (2 samples) 1944, February 20th, and on July 7th 1945.

The material has been collected through the kind assistance of Conservator DITLEF RUSTAD at Bergen University Biological Station, which during the war was located at Hermannsverk in the Sogne Fjord region. Mr. RUSTAD has also kindly supplied me with the hydrographic data for the prawn grounds shown in table L.

TABLE L. Vestlandet.

Locality	Date 1944	Depth m	T° C	S o/oo
Luster Fjord	July 4.	125	6,95	34,90
—»—	Oct. 17.	125	7,01	,76
Vetle Fjord	July 21.	300	6,87	,97
Sogndals Fjord	Oct. 20.	262	5,92	,05

The prawns in the Luster Fjord and the Vetle Fjord seem to have about the same growth rates and sexual developments. In the Sogndals Fjord, however, we find a comparatively slow growth combined with a retarded sexual development. To illustrate the variation it will suffice to discuss only the Luster Fjord and the Sogndals Fjord (fig. 36). The Luster Fjord is quite open with no submarine barrier at the mouth which could

prevent the exchange of water even in the deeper parts. The Sogndals Fjord is, on the other hand, a typical threshold fjord with a barrier 20—30 meters below surface at the entrance.

When 1½ years of age the prawns in the Luster Fjord measure 77,80 mm, in the Sogndals Fjord 60,79 mm. The size distribution in the Luster Fjord indicates that the prawns here are mature males, while in the Sogndals Fjord a majority of the prawns probably are immature.

When 2½ years of age 28 per cent of the Luster Fjord prawns have changed into females measuring 107,80 mm, while 72 per cent spawn as males for the second time at a size of 92,59 mm. The total mean size of the year group is 96,73 mm. In the Sogndals Fjord 98 per cent of the year group spawn as males having reached a size of only 83 mm. Thus in both localities a comparatively small percentage of the age group mature as females when 2½ years old, although the tendency to remain males is strongest in the Sogndals Fjord.

When 3½ years of age the whole age group in the Luster Fjord spawns as females at a size of 123,17 mm. In the Sogndals Fjord the whole year group likewise matures as females, but here the size is only 106,16 mm. The prawns in the Sogndals Fjord can be traced till an age of 4½ years when they, on an average, measure 128,53 mm. In connection with the growth curves shown in fig. 36 it may be noted that the bottom temperature in the Sogndals Fjord is about 1° C lower and the water less saline than that found in the Luster Fjord and the Vetle Fjord.

The prawn populations found in the different localities in the district of Vestlandet show no unusual trends in their life histories which have not been commented upon before. It is again revealed that the growth can vary considerably from one field to another, and that the growth rate in early life seems to influence the rate of transition into females later in life. The most rapid growth and maturing in the district are observed in the Radøy Fjord, while the most slow-growing prawn population is found in the Sogndals Fjord.

Møre and Trøndelag District.

I a previous chapter we have described the growth and development of the prawn from the Vigra Fjord in Møre district. Scattered samples have also been collected from other prawn grounds on this part of the coast (see chart fig. 2). Although these samples do not give a complete picture of the life history of the prawns on each separate ground, they give at least an idea of their general development. Samples have been obtained from the following localities:

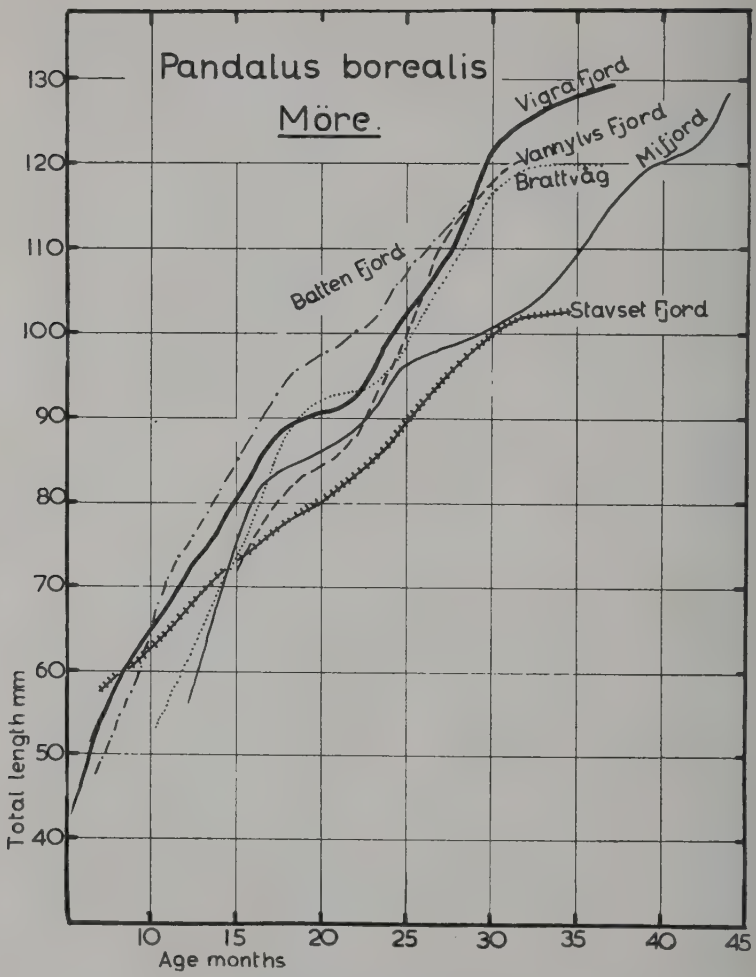

Fig. 37. The Growth Curves of the Prawns in Different Localities in the Møre District.

Batten Fjord, near the town of Kristiansund, 62° 56′ N. lat. 7° 46′ E. long. Depth 180 m. One sample from October 19th 1946 containing 513 prawns.

Vannylvs Fjord, 62° 05′ N. lat. 5° 30′ E. long. Depth 150—165 m. One sample from August 7th 1943 containing 590 prawns.

Bratvåg or *Drøna ground*, 62° 37,8′ N. lat. 6° 29,5′ E. long. Depth 110—150 m. Two samples from February 7th and March 18th 1944 containing respectively 403 and 396 prawns.

Mi-Fjord, 62° 38,2′ N. lat. 6° 36′ E. long. Depth 220—240 m. Three samples containing 137, 577 and 533 prawns collected respectively on May 8th, July 9th 1943 and on September 9th 1943. This ground is an eastern extension of the Bratvåg ground, but separated from the latter by a ridge with a saddle depth of about 100 meters.

Stavset Fjord, 62° 30,5′ N. lat. 6° 31′ E. long. Depth 90—110 m. One sample containing 504 prawns taken on November 24th 1943. The prawn ground forms a depression in the middle of the fjord, surrounded by shallow water on all sides.

As far as can be ascertained from the material the periods of spawning and hatching in these localities are much the same as previously described for the Vigra Fjord. The growth curves for the separate grounds in the Møre district are shown in fig. 37, and in table LI are given some of the details in regard to the variations in sexual development at an age of approximately 1½ and 2½ years.

At the age of 1½ years only an insignificant number of prawns mature as females in any of these fjords. The prawns in the Batten Fjord show a faster rate of growth in early life than any of the other populations in the same district. It is of interest to note that in the Mi Fjord only a small part of the age group appear to mature as females when 2½ years old, while the percentage of mature females at that age is greater in the other localities. The Mi Fjord prawns have also had the smallest increment of growth during the past year in comparison with that of the other prawn populations.

TABLE LI. Møre District.

Locality	Age months	Males		Females		Total mean size mm
		per cent	size mm	per cent	size mm	
Batten Fjord	18	97	95,03	3	104,25	95,29
Brattvåg	21	98	94,87	2	95,04	94,90
Mi Fjord	16	100	82,04	—	—	82,04
Stavset Fjord	19	98	79,18	2	88,14	79,39
Vannylvs Fjord	15	100	72,24	—	—	72,24
Batten Fjord	30	—	—	100	116,60	116,60
Brattvåg	33	55	117,55	45	124,92	120,89
Mi Fjord	28	87	98,53	13	106,90	99,59
Stavset Fjord	31	30	96,14	70	104,57	101,97
Vannylvs Fjord	27	24	101,60	76	112,73	110,03

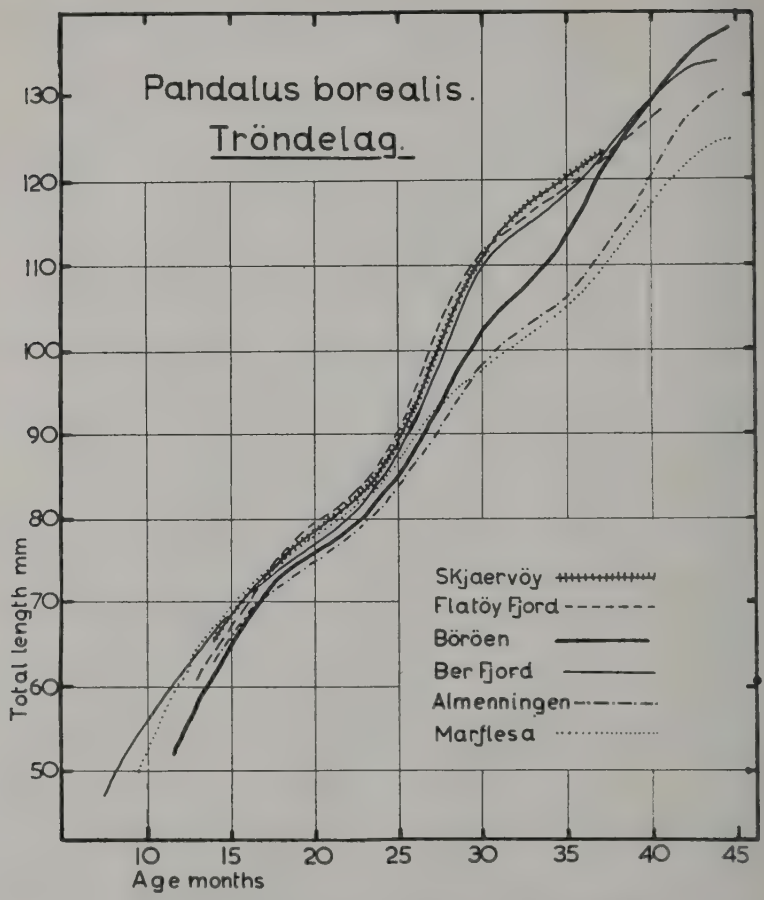

Fig. 38. The Growth Curves of the Prawns in Different Localities in the Trøndelag District.

In connection with the fast rate of growth observed in the Batten Fjord it must be emphasized that the material from this locality is collected in 1946 while on other grounds the material is from 1942—44. On the coast of Møre there was a heavy influx of cold bottom water in 1940—1943 which may explain the growth variations found in that region. Eggvin (1948 pp. 72) mentions that the temperature variations in the deeper water in the Møre district follow a course similar to that

found in the Vest Fjord farther north along the coast. The prawns from the Batten Fjord treated above are born in 1944—46, i.e. in a period with steadily increasing bottom temperatures, while the prawns in the material from other grounds have grown up during the preceding series of cold years. This temperature variation may possibly account for the differences noted in growth and maturing.

In the *Trøndelag* district we have previously discussed in detail the life history of the prawn from the Brands Fjord. Here the different year classes showed great variations in growth and sexual development. When 2½ years of age between 54 and 86 per cent of the prawns matured as females, the percentage varying in the different year classes. When 3½ years of age all were females.

From the Trøndelag district we have at our disposal, besides the material from the Brands Fjord, also scattered samples from other grounds (see chart fig. 2).

Børøen ground, 64° 16,2′ N. lat. 10° 14,3′ E. long. Depth 180—230 m. Three samples containing 530, 597 and 725 prawns, collected respectively on April 8th, May 16th and on June 2nd 1944.

Almenningen, 64° 1,8′ N. lat. 9° 59,3′ E. long. Depth 200 m. One sample containing 915 prawns taken on June 26th 1944.

Ber Fjord, 64° 10,3′ N. lat. 10° 12,4′ E. long. Depth 170 m. One sample containing 320 prawns taken on December 15th 1944.

Marflesa, 64° 10,1′ N. lat. 10° 17,5′ E. long. Depth 180 m. One sample containing 457 prawns taken on February 14th 1945.

Flatøy Fjord, 64° 16,2′ N. lat. 10° 14,3′ E. long. Depth 225 m. Two samples containing 561 and 493 prawns taken respectively on May 29th and June 20th 1945.

Skjærvøy ground, 64° 17′ N. lat. 10° 19′ E. long. Depth 200 m. One sample containing 602 prawns taken on July 5th 1945.

While taking the prawn samples from these localities a fine-meshed covering was used over the codend of the prawn trawl. The samples listed above thus contain prawns caught both in the codend proper as well as in the fine-meshed bag. The growth curves for the prawns from the various localities are shown in fig. 38.

As will be seen from the figure the growth and development on all these grounds are quite uniform during the first two years of life. When 1½ years of age they measure between 72 and 76 mm, and the majority of the prawns of this size may be expected to be mature males. When 2½ years of age the size of the prawns shows a greater variation. The prawns from Marflesa, Almenningen and Børøen have attained a mean size between 98 and 102 mm, while those from the Ber Fjord, Skjærvøy and Flatøy measure 110—112 mm. It is not possible to state with any

degree of certainty what proportion of the prawns become ovigerous when 2½ years of age in the different localities. The composition of the material indicates, however, that at Marflesa and in the Flatøy Fjord all prawns may mature as females at that age, while on other grounds perhaps between 35 and 63 per cent of the age group may reach that stage. In most localities the prawns can be traced till an age of 3½ years when they have attained a size varying between 122 and 136 mm.

Nordland District.

In previous chapters we have discussed the life history of the prawn populations from some fjords in the Nordland district, namely from the Mist Fjord, the Ofoten Fjord and the Eids Fjord. In these localities the prawns showed great variations both in growth and sexual development.

Some material has been collected also from other grounds in the district of Nordland (see chart fig. 3).

Søvik near Sandnessjøen, 65° 56′ N. lat. 12° 24′ E. long. Depth 156 m. One sample from April 28th 1942 containing 226 prawns.

Morsdals Fjord, 67° 04′ N. lat. 14° 07′ E. long. Depth 130 m. One sample containing 291 prawns collected on October 25th 1946. The Morsdals Fjord is a narrow inlet on the south side of the Vest Fjord. The entrance is barred by a threshold at a depth of 75 meters, and at its inner end it is separated from the Beiaren Fjord by a very shallow area.

North Folla, 67° 41,5′ N. lat. 15° 09′ E. long. Depth 225— 250 m. The material consits of the samples listed in table LII.

The Folla Fjord north of the town of Bodø is a large open inlet from the Vest Fjord. The Folla is divided into two main parts, the North-Folla and South-Folla. The prawn ground is located in the central part of the North-Folla where a deep channel with soft bottom is found.

TABLE LII. North Folla

Date	No. of prawns
March 24. 1942	89
April 10. »	115
April 21. »	383
July 10. 1943	461
Febr. 2. 1944	435
Febr. 18. »	611
March 9. »	333
April 2. »	586
Sept. 7. 1946	277
Total	3290

The hydrographic conditions in the fjord have been described by T. Soot-Ryen (1932). The Folla Fjord is in the deeper parts from about 200 meters downwards filled with water with temperatures of more than 6° C and salinities of more than 34,80 ‰, the same type of water which also is to be found in the Vest Fjord. A hydrographic station taken by Soot-Ryen in the North-Folla on August 9th showed that the bottom temperature (250 m) was 6,43° C and the salinity above 34,56 ‰. A station taken by the present author on February 17th 1944 showed a bottom temperature (230 m) of 6,5° C and a salinity of 34,37 ‰. At the entrance of the Folla Fjord the saturation of oxygen from 100 meters downwards according to Soot-Ryen varies between 86 and 91,5 per cent, the highest value being found at 400 meters.

Øks Fjord, 68° 24′ N. lat. 15° 23′ E. long. Depth 165—220 m. The prawn material consists of the following samples:

March 3. 1944	inner	prawn field	360 ind.
—»—	middle	—»—	481 »
—»—	outer	—»—	285 »
Sept. 14. 1945	outer	—»—	304 »
—»—	inner	—»—	306 »
Total			1736 ind.

The Øks Fjord is a narrow fjord lying inside the skerry guard at the innermost part of the Vest Fjord. It has the character of a threshold fjord, the entrance being covered by a large number of islets and skerries.

In the Øks Fjord there are three small prawn fields located at respectively the outer (165 m), middle (220 m) and inner part of the fjord (180 m).

The general hydrographic conditions will appear from the stations shown in table LIII.

TABLE LIII. Øks Fjord.

Depth	March 4. 1944			Sept. 14. 1945	
	T° C	S 0/oo	Oxy.	T° C	S o/oo
0	2,42	32,30	3,20	11,83	31,59
10	2,81	,42	7,40	10,70	32,18
25	3,80	,61	7,40	10,63	,51
50	4,37	,78	7,09	6,09	33,69
75	4,64	,96	7,10	5,72	,81
100	5,65	33,37	5,88	5,21	,80
125	5,48	,68	5,78	5,05	,78
150	5,44	,49	5,68	5,01	,78
190	—	—	—	5,00	,79
200	5,44	,18	5,81	—	—

The bottom temperatures in the Øks Fjord are somewhat higher than those found in the Mist Fjord, while the salinities of the bottom water are somewhat lower. The hydrographic observations confirm that warm and salt water, on account of the threshold, cannot penetrate along the bottom of the Fjord from outside.

Kirke Fjord at Reine, 67° 57′ N. lat. 13° 04′ E. long. Depth 130 m. One sample from March 22nd 1948 containing 341 prawns.

The Kirke Fjord is a narrow inlet cutting into the Moskenes Island, one of the outer Lofoten islands. The fjord has a shallow threshold at the entrance.

Vest Fjord. No special prawn grounds fished commersially are found in the Vest Fjord proper; but experimental trawling has been carried out and samples taken occasionally by our fishery research ships. We have material at disposal from the following localities:

Off *Balstad*, 68° 03′ N. lat. 14° 25′ E. long. Depth 300 m. Off *Henningsvær*, 67° 46,8′ N. lat. 13° 37′ E. long. Depth 300 m. A combined sample from these localities taken on June 16th contains 568 prawns. Off *Svolvær* (Høla), 68° 13,5′ N. lat. 14° 40′ E. long. Depth 300 m. One sample from October 19th 1946 containing 203 prawns.

All samples are taken in or near the deep channel running along the middle part of the Vest Fjord. The hydrographic conditions in the bottom layers of the Vest Fjord are generally quite uniform all over the fjord. The hydrography and the life history of the prawn will be specially treated later in this chapter.

The growth curves of the prawns in the different localities listed above, with the exception of the Vest Fjord, are shown in fig. 39. The figure shows that there is a similar variation in rate of growht from one locality to another as was found in the Møre district.

When 1½ years of age the prawns have a size varying between 69 and 84 mm. The smallest prawns are found in the Øks Fjord, the largest in the Søvik area and in the Morsdals Fjord. In the Øks Fjord probably only a part of the prawns (the largest ones) are actively spawning males when 1½ years of age. The same can be said about the prawns from the Kirke Fjord which have a mean size of about 71 mm. On the North-Folla the mean size is approximately 76 mm and the whole age group probably is composed of active males.

In the Morsdals Fjord the prawns attain a size of 83 mm, and here apparantly about 10 per cent of the age group mature as females, while the rest are active males. Also in the Søvik area some prawns mature as females when 1½ years of age.

One year later, at an age of 2½ years, the mean lengths of the different populations show the same variations as a year before. Again

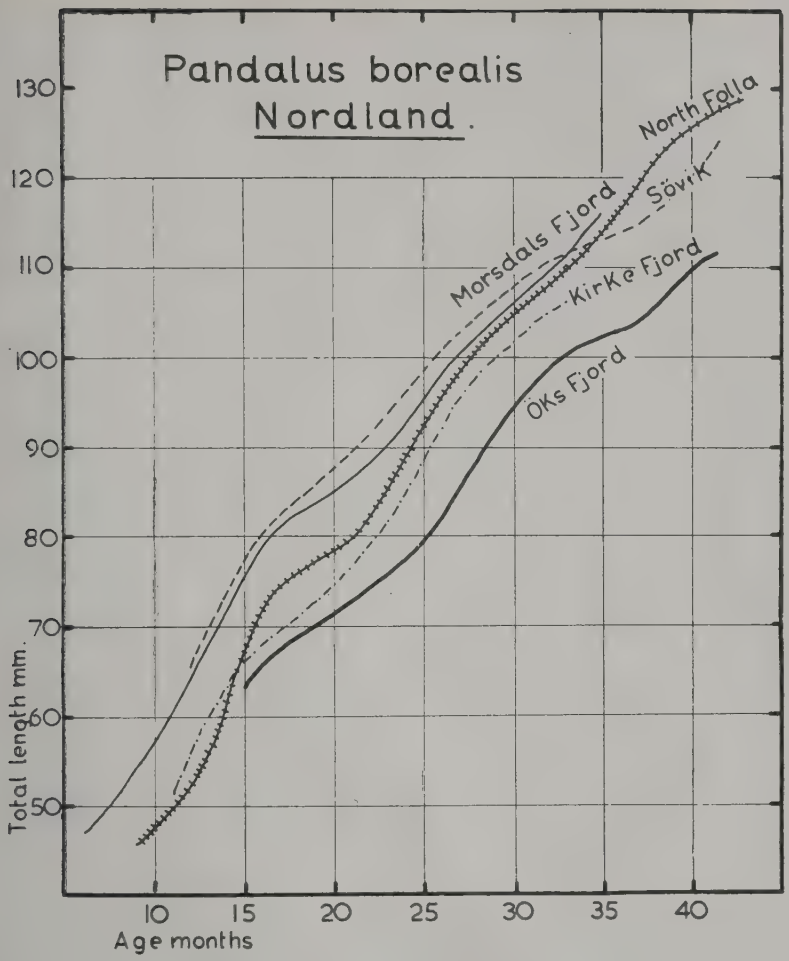

Fig. 39. The Growth Curves of the Prawns in Different Localities in the Nordland District.

it is the prawns from the Øks Fjord which show the least growth. The samples from this locality indicate that about 12 cent of the age group become ovigerous while the rest are functioning as males at that age. The mean size of the age group is about 94 mm.

In the *Kirke Fjord* the mean size is about 102 mm and it is expected that 40—50 per cent of the age group will spawn as females. In *North-Folla* the prawns measure on an average 104 mm and 45—70 per cent of

the age group apparently spawn as females. In the *Morsdals Fjord* and *Sørvik area* the mean size of the prawns is respectively about 106 and 108 mm. In both these localities all the 2½ year old prawns seem to spawn as females.

When 3½ years of age the prawns in all the localities treated above spawn as females, some for the first time, others for the second time and some for the third time.

The most striking feature of the Øks Fjord and the Kirke Fjord grounds is the low rate of growth and the small size of the ovigerous prawns. This is the same phenomenon as was observed in the Mist Fjord which also is situated in the Nordland district. All these fjords have some features in common, namely a shallow threshold barring the entrance, and comparatively low bottom temperatures and salinities.

In the *Vest Fjord* proper the prawns show no new features in regard to growth and development which have not been touched upon before. But in the Vest Fjord we have temperature observations over a series of years which may throw some light upon the reasons for the variations found in the different prawn populations and the different year classes. The growth curves of the prawns in the Vest Fjord as they appear in two samples collected respetively in 1943 and 1946 are shown in fig. 40. In the figure are added the years in which the different broods are born, and likewise the temperatures in a depth of 300 meters in June of the year when the brood was born.

The prawn sample from 1943 contains prawns born in 1942 (I-group), 1941 (II-group) and 1940 (III-group). The sample from 1946 contains prawns born in 1946 (0-group), 1945 (I-group), 1944 (II-group) and 1943 (III-group). The various broods in each separate sample have been combined in a series so as to give the general picture of the life history of the prawn in this locality.

In the sample taken in 1946 we find one individual about 5½ months old measuring 37 mm (1946-brood). At the commencement of the spawning season a year later the mean size is 78,91 mm (1945-brood). One per cent of these prawns are found to function as females at that age, while the rest are males. One year later 97,7 per cent of the year class are spawning as females, while 2,7 per cent still are males. The mean size of the whole group is 106,00 mm (1944-brood). When 29½ months of age the whole group consists of females having attained a mean length of 123,97 mm (1943-brood).

In the sample taken in 1943 we find a group of 13½ months old prawns with a mean length of 51,94 mm. The sample is taken in June, and still another 4 months of growth will pass before spawning time in the autumn. By that time possibly the largest individuals will be able to

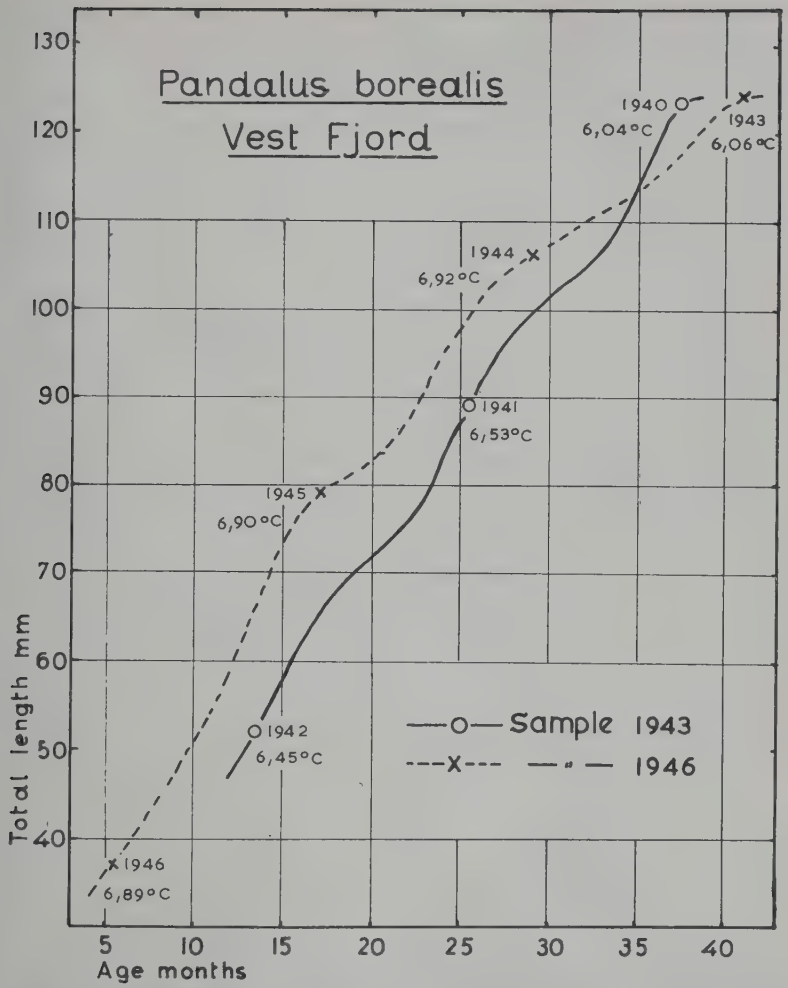

Fig. 40. The Growth Curves of the Prawn in the Vest Fjord. The 1943 Sample containing Broods Born in 1940—41—42, and the 1946 Sample Containing Broods Born in 1943—44—45—46. The Temperatures in Depths of 300 Meters in June of the Respective Years of Birth.

mature as males (1942-brood). One year later, when 25½ months old the prawns have attained a mean size of 89,46 mm (1941-brood). At this age 46 per cent of the year class are transitionals or maturing as females while the rest are still males. Probably the proportion of females

will increase a little before spawning sets in 4 months later, but the present size indicates that not the whole year class will reach the female stage when 2½ years old. When 37½ months of age the prawns have grown to 123,70 mm (1940-brood). Now all the males have changed their sex and the whole year class consists of females.

Summarily we can say that in the sample from 1946 the prawns have a more rapid growth, and that almost all of them change into females when 2½ years of age, while the sample from 1943 contains prawns with a low rate of growth in early life combined with a lower number of females at an age of 2½ years.

The reason for such a variation in growth may possibly be found by a closer study of the conditions under which the prawns have lived. The hydrography of the Vest Fjord has been studied for a series of years by Eggvin in connection with the Lofoten fishery. The hydrographic conditions in the bottom layers of the Vest Fjord are generally quite uniform and show little variation from one year to another, or from season to season. However, in a report Eggvin (1948) remarks that in 1940 we had the most drastic exchange of water masses along the Norwegian coast hitherto experienced. The exchange was characterized by the deep water becoming considerably colder than it had been for a number of years. Simultaneously the salinity decreased while the specific gravity increased somewhat. Such a hydrographic situation was also found in 1941—43.

Eggvin has kindly supplied me with the mean bottom temperatures at 300 meters off Skrova in the Vest Fjord during June for a period of years:

1936 7,04° C	1941 6,53° C
1937 6,80° »	1942 6,45° »
1938 6,80° »	1943 6,06° »
1939 7,05° »	1944 6,92° »
1940 6,04° »	1945 6,90° »
	1946 6,89° »

As will be seen from the table the temperatures in the deeper layers of the Vest Fjord were between 0,5° and 1° C below normal in the years 1940—1943. In October 1942 temperatures below 5° C were noted in depths down to 250—260 meters, i. e. about 2° C below normal. In 1944 and the following years great masses of relatively warm Atlantic water moved in towards the coast and the conditions again returned to normal.

The description above of the hydrographic conditions shows that the slowgrowing prawns contained in the sample from 1943 all their life had

been subject to temperature conditions which were abnormally low for that specific area. The more rapid growing prawns in the sample from 1946, with the exception of those born in the cold year of 1943, had most of the period lived under normal temperature conditions. We can presume that the rate of growth and the sexual development among the prawns in the Vest Fjord normally have a trend as indicated by the prawns in the sample from 1946.

Troms district.

In the Troms district prawn samples have been collected from a number of localities lying quite a distance apart (see chart fig. 3).

The Vågs Fjord, 68° 43′ N. lat. 16° 45′ E. long. Depth 240 m. The material consists of 3 samples containing 514, 738 and 344 prawns collected respectively on February 24th 1944, September 26th 1945, and on September 14th 1946.

The Vågs Fjord prawn ground lies in a deep hollow between the two islands Hinnøy and Rolla. The hydrographic situation on the prawn ground is shown by a station taken on February 24th 1944, (table LIV).

TABLE LVI. Vågs Fjord.

Depth	T° C	S o/oo
0	4,23	33,27
10	4,21	,24
25	4,94	32,25
50	5,96	33,85
75	6,07	,98
100	6,11	,76
125	6,31	34,07
150	6,50	,22
200	6,72	,41

The observations indicate that the prawn ground is covered by comparatively warm and salt water of the type usually found in open fjord.

Kvæ Fjord, 68° 50′ N. lat. 16° 03′ E. long. Depth 170 m. One sample of 344 prawns collected on October 14th 1946.

Bals Fjord, 69° 22,5′ N. lat. 19° 05′ E. long. Depth 180— 190 m. The prawn material consists of of the following samples:

July	6. 1943	738 prawns
Sept.	24. 1945	563 »
Sept.	17. 1946	554 »
Aug.	28. 1947	313 »
Total		2162 prawns

The long and narrow Bals Fjord is situated a short distance south of Tromsø. The fjord has a threshold at its entrance with a sadle depth of 30 meters. Commercial prawn trawling is carried out on a comparatively large scale in a deep channel situated about the middle of the fjord. On account of the threshold warm water of Atlantic origin cannot penetrate into the fjord and the bottom is covered with cold water of coastal type. The hydrographic stations listed in table LV illustrate the general conditions on the prawn field.

TABLE LV. Bals Fjord.

Depth m	Sept. 24. 1945		Sept. 17. 1946		Aug. 28. 1947			Oct. 5. 1950	
	T °C	S o/oo	T °C	S o/oo	T °C	S o/oo	Occ.	T °C	Occ.
0	8,48	32,26	8,92	32,09	11,80	26,79	7,34	7,65	—
10	7,39	,26	8,44	,21	8,34	32,24	7,06	7,72	6,20
25	7,47	,79	8,59	,81	7,27	,70	7,04	7,90	5,98
50	6,56	33,01	7,83	33,03	5,94	,89	7,65	7,35	5,93
75	3,78	,17	4,23	,18	4,00	33,22	7,08	4,91	5,89
100	2,62	,37	3,28	—	3,27	—	7,21	3,77	5,98
125	2,11	,48	2,89	,45	2,97	,50	6,82	3,08	5,93
150	1,64	,56	2,30	,49	2,60	,56	6,73	2,54	5,73
170	—	—	—	—	—	—	5,62	2,40	4,80
175	—	—	2,11	,55	2,62	,62	—	—,	—

The bottom temperatures are somewhat lower than those found in the Mist Fjord which also is a threshold fjord. H. Klær (1907) mentions that in the deep channel of the fjord, the fauna seems to have a considerably more arctic character than in any other part of the fjord. This characterization is also confirmed through our own investigations in the Bals Fjord.

Ulls Fjord, 69° 55′ N. lat. 20° 07′ E. long. Depth 200—250 m. One sample of 313 prawns collected on September 2nd 1947.

Kvænangen Fjord, 69° 54′ N. lat. 21° 44′ E. long. Depth 180—190 m. One sample of 258 prawns collected on September 25th 1946.

The growth curves of the prawns from the localities listed above are shown in fig. 41. All the prawn populations in these fjords show different growth rates and vary in their sexual development.

The spawning on all the prawn grounds listed above seems to start earlier in the autumn than what is usual on the more southern grounds. Spawning of the prawns in the Bals Fjord has already commenced by July 6th when we find two berried individuals. Towards the end of August 41 per cent, and the end of September 48 per cent of the females

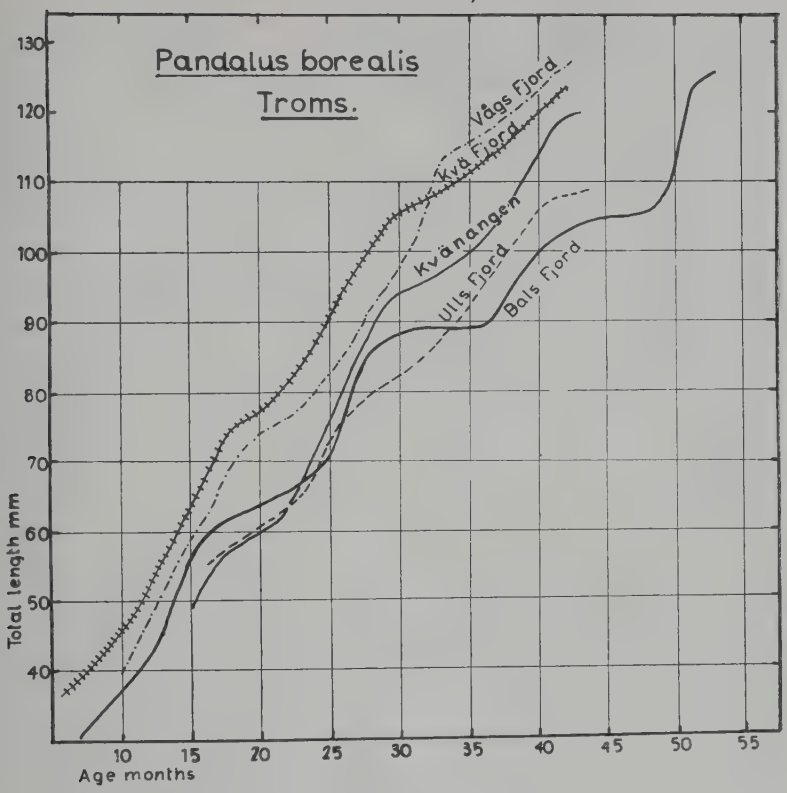

Fig. 41. The Growth Curves of the Prawns in Different Localities in the Troms District.

are ovigerous. The spawning period here obviously lasts for more than 3 months. In the Ulls Fjord 75 per cent of the females are ovigerous by September 2nd. In the Kvænangen Fjord 40 per cent of the females are ovigerous by September 25th. In the Kvæ Fjord, however, the spawning season starts much later. Here only 0,6 per cent of the females were berried on October 14th. In the Vågs Fjord spawning had not started by September 26th. The duration of the ovigerous period and the dates of hatching cannot be ascertained from the material.

The youngest prawns in the material from the Troms district are obtained from Bals Fjord. On July 6th 1943 a plankton net fastened to the trawl wire was dragged near the bottom for one hour. This experiment resulted in the capture of 58 prawns with a mean size of only 18,6

mm. These prawns must have been hatched in the spring of the same year and have reached the stage when they leave the pelagic existence and settle to the bottom.

In the different localities in the Troms district the size of the prawn can be calculated at a season when they are ready for spawning, i.e. at an approximate age of $1^1/_2$ years, $2^1/_2$ years etc. This enables us also to compare directly the growth and the sexual development in each locality.

When $1^1/_2$ years of age, the prawns have attained the size and maturity indicated in table LVI.

TABLE LVI. Troms District.

Locality	Size mm	Youngs per cent	Males per cent	Females per cent
Ulls Fjord	54,75	100	0	0
Kvænangen	56,07	100	0	0
Bals Fjord	60,10	95	5	0
Vågs Fjord	64,29	78	22	0
Kvæ Fjord	73,94	0	94	6

In the localities with the lowest rate of growth the prawns do not mature as males when $1^1/_2$ years of age, while in the Kvæ Fjord where the prawns have the most rapid rate of growth, the prawns not only reach their male capacity but a few are also able to develop into females. In the case of the Vågs Fjord the state of the sexual organs of the young prawns were not examined, but the percentages listed in the table have in this case been calculated on the basis that the largest prawns of the age group measuring 64—69 mm may be able to function as males. This has been found to be the case for instance in the Bals Fjord where a close examination of the maturity of the testes was made.

When approximately $2^1/_2$ years of age, the different prawn populations show the sexual development and mean lengths listed in table LVII.

TABLE LVII. Troms District.

Locality	Males		Females		Total mean size mm
	per cent	size mm	per cent	size mm	
Ulls Fjord	99	79,34	1	92,75	79,50
Bals Fjord	100	88,51	0	—	88,51
Kvænangen	74	90,63	26	98,37	92,59
Vågs Fjord	76	88,72	24	105,21	92,70
Kvæ Fjord	9	100,33	91	106,05	105,63

The table shows clearly that in localities with a high rate of growth, a large number of prawns mature as females when 2½ years of age, while in localities with a slow rate of growth (Bals Fjord, Ulls Fjord) few or non of the prawns reach that stage, but spawn instead as males for the first time.

When 3½ years of age, the prawn populations show the features illustrated in table LVIII.

TABLE LVIII. Troms District.

Locality	Males		Females		Total mean size mm
	per cent	size mm	per cent	size mm	
Bals Fjord	99	100,86	1	107,75	100,91
Ulls Fjord	54	97,79	46	115,54	105,95
Kvænangen	—	—	100	118,03	118,03
Kvæ Fjord	—	—	100	123,86	123,86
Vågs Fjord	—	—	100	126,45	126,45

In Kvænangen, in the Kvæ Fjord and in the Vågs Fjord the prawns are spawning as females partly for the second time and partly for the first time when 3½ years of age. In the Bals Fjord where we have the lowest growth rate, very few individuals mature as females. In the Ulls Fjord 46 per cent of the prawns spawn as females at that age, the rest functioning as males for the second time in life.

It is only in the Bals Fjord we are able to trace the prawns beyond the age of 3½ years. The samples taken in the autumn of 1945, 1946 and 1947 show that all the prawns have changed into females which become ovigerous when 4½ years of age having attained a size of 124—125 mm. However, the sample taken on July 6th 1943 indicates that also at that age we may expect variations in the development. In the sample mentioned only 15 per cent of the IV-group approaching sexual maturity will spawn as females, while 85 per cent will still function as males. The mean lengths are 101,92 mm for the males, 119,99 mm for the females, and only 104,57 mm for the whole age group. The final transformation into females will apparently in this case not be completed till the prawns are approaching the age of 5½ years.

The general development of the prawns in the Bals Fjord seems to pass through the following successive stages: immature youngs 1½ years of age, males 2½ and 3½ years of age and spawning females 4½ years of age. This is largely a repetition of the life history previously described in the case of the Mist Fjord. Single years, as for instance

1943, may show a development more related to that found in Spitsbergen waters.

It is a significant feature that prawn populations with a low rate of growth combined with a prolonged protandric development also spawn early in the autumn and thus presumeably have an unusual long ovigerous period. This feature is found at Spitsbergen and Jan Mayen, as well as in the Bals Fjord and the Ulls Fjord.

Summary and Conclusions.

The deep sea prawn, *Pandalus borealis*, is a crustacean with a life history of a very complex nature. Through the investigations by various authors in the 1930'ies it was discovered that the deep sea prawn is a protandric hermaphrodite, i. e. the prawns have the ability to change their sex in such a manner that they early in life act as males and later on change their sex and act as females. The investigations indicated further that the growth and maturing of the prawn were largely uninform in the different areas investigated, as for instance on the Pacific Coast of Canada, in the Gullmar Fjord (Sweeden), in the Oslo Fjord (Norway) and in the Skagerak. In all these localities the prawns generally functioned as active males when 1½ years of age and at a size of about 90 mm, then changed sex and spawned as females when 2½ years of age at a size of approximately 120 mm. In exceptional cases a few prawns could mature as females when 1½ years of age, and it was surmised that a few prawns could act as spawning males for more than one year.

In 1942 the present author published a report on the deep sea prawn in Spitsbergen waters. The investigations proved that the growth and sexual development in this Arctic area were much slower than in any of the localities investigated previously. In Spitsbergen waters, for instance, the prawn did not mature as male till 3 years of age, acted as male also in the fourth year, and did not reach the female stage till 5 years of age.

The idea was naturally born that the great differences found in the life histories of these widely separated prawn populations were largely due to environmental factors. If such were the case several questions presented themselves. For instance, did there really exist a graded geographical variation in growth and sexual development of the prawn in conformity with the theory that the farther north the prawns were found, or the colder their environment was, the slower their growth and maturing? And if this were found to be the case, by which characters would such a graded variation be expressed in the different prawn populations?

To answer these questions it was natural to pursue the prawn investigations on the hypothesis that somewhere along the extended Norwegian coast we might be able to find prawn populations which by their growth and development would form natural intermediate links between the prawns in Southern Norway and those in Arctic waters. The collection of prawn samples from different localities was started in 1943 and continued for a number of years.

The present report deals with the life history of different prawn populations distributed from Southern Norway to the Arctic waters of Spitsbergen and Jan Mayen. The results of the investigations emphasise the fact that it is necessary to revise any previous conceptions that the life history of the deep sea prawn should be largely uniform in its whole area of distribution. The growth and maturing change, not only from one locality to another, but also from brood to brood born in different years in one and the same locality.

In reviewing the material at disposal we find, however, certain features common to all the different populations, and we also find indicated the basic rules for the reaction of the prawns towards changes in the surroundings. The results seem to prove that decreasing temperatures in the sea cause slower growth and retarded maturing. This means for one thing that generally we will find more slow-growing and slow-maturing prawns the farther north we go. And further more, in Norway prawn fields are found in many of the socalled "threshold" fjords which have a shallow barrier across the entrance. In these fjords we often find lower temperatures and salinities near the bottom than on the prawn fields situated in "open" water. The prawn populations in these threshold fjords may, without special regard to geographic latitude, show a life history approaching that of the slow-growing prawns in Arctic waters. As examples we may refer to the Sogndal Fjord in Vestlandet district, the Mist Fjord in Nordland, and the Bals Fjord in Troms district.

In regard to the spawning season of the prawn, we also in this respect find features which seem to conform to certain rules. On the majority of the grounds, particularly in Southern Norway, the prawns spawn in October—November, the females carrying their eggs for about 5 months till the eggs hatch in March—April. However, in the Arctic waters of Spitsbergen spawning takes place 3 months earlier than in Southern Norway, the eggs hatching 2 months later during next spring, the ovigerous period thus lasting for about 9 months. The Jan Mayen area shows a similar picture, while the threshold fjords in Norway present intermediate features. The Bals Fjord and other fjords in Northern Norway have a probable ovigerous period of 7—8 months, while the prawns

in the Mist Fjord further south carry their eggs for 6 months. In all these localities the spawning commences earlier in autumn than what is the case in Southern Norway. The general rule seems to be that the colder the environment, the earlier the spawning and the longer the ovigerous period.

Eggs of fishes and other marine forms need a longer time for hatching in low temperatures, and the same seems to be the case with the eggs of the deep sea prawn. In the case of *Pandalus borealis* Nature seems to have provided for this contingency through early spawning and late hatching in cold surroundings, i. e. through a prolonged ovigerous period.

In ordinary circumstances all individuals within a prawn population have the tendency to spawn as active males when 1½ years of age and as females when 2½ years of age. But in many localities along the Norwegian coast and in Arctic waters the prawns mature as respectively males and females much later in life. It is significant that in spite of the great differences in age when maturing, both males and females in the different localities are of approximately identical size upon reaching sexual maturity. There is obviously an intimate connection between the process of sexual maturing and the rate of growth in the different areas. The basic principle seems to be that a particular prawn population, or a single year class in any population, having a high rate of growth, produces sexually mature males and females earlier in life than does a prawn population with a low rate of growth. And furthermore, in a prawn population or any year class of prawns the number of individuals maturing respectively as males and females is determined not so much by the age as by the size attained before spawning time.

The process of division of a year class into two or three fractions of different sexual characters (see fig. 13 and 20) is the mechanism by which Nature regulates the number of prawns which are to stay immature, or which shall spawn as males and females, all in relation to the local rate of growth, i. e. in relation to the environment. In the Oslo Fjord we can for instance find a year class of prawns, 1½ years of age, divided into three fractions containing respectively immature youngs, mature males, and spawning females. Older age groups in any locality usually divide so as to form one male and one female fraction.

The principle governing the mechanism of division seems to be that the largest individuals in any group of prawns change into females, while the fraction containing the smaller prawns constitutes the males' part. The very smallest individals of a year class may form the third fraction of immature youngs. This division of an age group into different sex categories is closely connected with the attainment of a more or less definite size level. If for instance an age group has attained a mean size of 80—90 mm in autumn only a few individuals will mature as females.

If the mean size is 100—110 mm perhaps 25—75 per cent will be females. Age groups having attained a mean size of 120 mm will generally consist of females only. The lengths stated only indicate the trend of sexual development. Variations in the relationship can be found in the different localities.

The sex division within a group of prawns having functioned as males generally starts in winter and continues throughout the following spring. The general rule seems to be that the largest males of the group undergo the transformation into females first. The individuals which have succeeded in the transformation have in the subsequent months an accelerated rate of growth, while the prawns which do not succeed in changing their sex apparently are restricted in their growth. As a natural consequence we find after a while that for instance an age group of 2½ year old prawns can consist of two distinct fractions, one size group of small males, and another one of large females, but both of identical age.

Environment, rate of growth, and sexual maturing are closely connected factors which find their expression in the varied life histories of the deep sea prawns on the many prawn fields between Skagerak and the Arctic seas. The prawn can sustain life, and multiply, within a wide range of temperatures, submitting to local conditions, growing and maturing in conformity to laws laid down by Nature. In relatively temperate surroundings the prawn grows fast and matures early, in the far north they grow slowly and mature late in life, while in between we find prawn populations which in their life history form the intermediate links between the two extremes (see fig. 42). From one growth type to another we find a natural transition expressed by a varied sexual division within the different age groups.

Protandric hermaphroditism is well known among other bottom invertebrates. THORSON (1936) mentions that there seems to be many hermaphrodites among the arctic forms of the lammelibranchs. In Northeast Grenland he found *Modiolaria laevigata* and *Modiolaria nigra* both of which were distinctly protandric hermaphrodites. In *M.laevigata* for instance all one year old animals function as males. In the second year the animal passes into the hermaphroditic stage when eggs develop, and in the third year the animal is purely female. In the genus *Cardium* the majority of boreal species are normally unisexual. THORSON found in Northeast Greenland that the *Cardium ciliatum* as well as *Cardium groenlandicum* were distinctly protandric hermaphrodites. Within the genus *Astarte* in Northeast Greenland the sexes had a peculiar distribution. A series of animals from one depth and one temperature contained a large majority of males, while at another depth and another temperature mostly females were found. It is indicated that the change of sex takes place after an intermediate resting period.

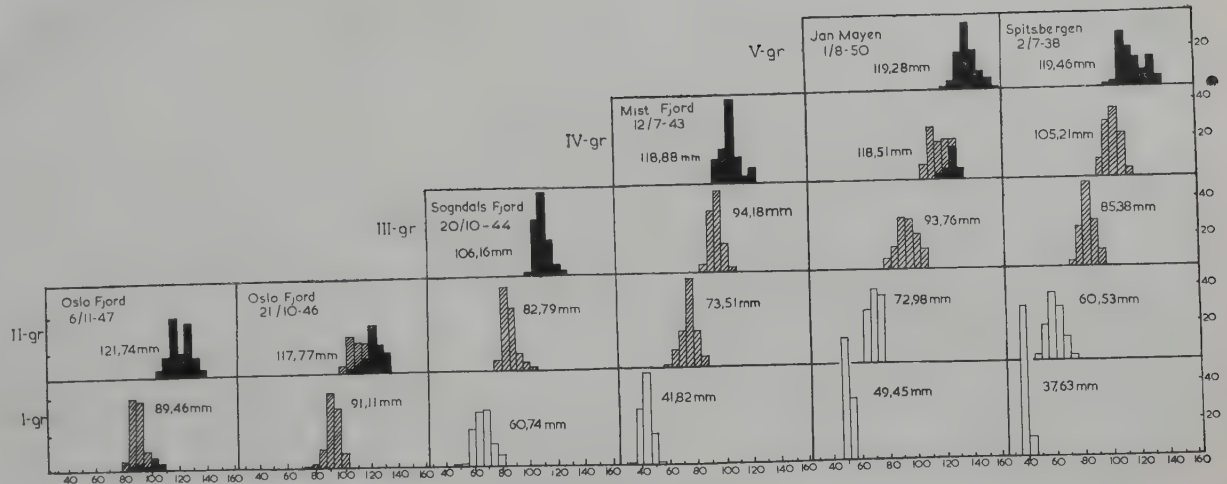

Fig. 42. The variations in Age, Size, and Sexual Development of the Deep Sea Prawn in Various Localities along the Norwegian Coast and in Arctic Waters. White: Youngs. Shaded: Males. Black: Females.

Among the marine prosobranchs we find similar traits. The common limpet, *Patella vulgata Linaeus*, is generally a protandric hermaphrodite, in which the change of sex may ocur when the animal is one year old, or may be delayed until later. Some animals may also remain males throughout life (ORTON 1928, 1946). M. DAS and G. SESHAPPA (1947) state that at first maturity the *Patella vulgata* has a size of 10 mm when all individuals are males. The first female appears at a size of 10—15 mm which is considered the transition stage. The number of females increases until a size of 56—60 mm when the females form about 80 per cent of the population. The ratio of the males to females show also a variation in conformity with the degree of exposure. The lower the animals are found from the high water mark, the larger the population of males.

The various protandric hermaphrodites among the bottom invertebrates mentioned above thus appear to have certain features in common with the deep sea prawn. The sex division which is related to size seems largely to follow the same pattern, and in most instances the surroundings seem to influence growth and thus also the sex composition of the population. The influence of the surroundings has been summarized in the following statement by THORSON (1936):

"It must be assumed that bottom invertebrates in Northeast Greenland seas will on the whole have a slow growth, a long life, and a late maturity, which means that the production must be very small."

The close connection between the surroundings and the growth and the maturing of various animals has often been stressed by a number of authors. In regard to crustacea I can mention E. EINARSSON (1945) who has studied the euphausiids of the North Atlantic. He considers it an established fact that there is a close correlation between the temperature and the maturing of the animals. In the euphausiids the correlation manifests itself thus: The lower the prevailing temperatures, the longer time is required before the animals become mature. This seems further to have a bearing upon the size at which the individuals become mature. Below a certain minimum temperature the development and the process of maturing cannot be accomplised in one year, but as the spawning season is strictly limited the animals live through a second growth season in which they become larger than the size attained by animlas maturing in one year. In the northern regions the mature euphausiids are thus larger than further south.

Also in the case of *Pandalus borealis* we have seen that the maturing is retarded in colder surroundings. On the other hand the mature females are approximately of identical length in northern and southern areas, although their age may be different.

As regards the duration and onset of the spawning EINARSSON also discusses the influence of external factors. He is of the opinion that the temperature does not offer a possible explanation in regard to the spawning of the euphausiids. He considers that there is a correlation between spawning and occurence of phytoplankton, and discusses the possibility that certain substances produced by the phytoplankton may act as a stimulus to the spawning. Similar suggestions have also been put forward by other authors.

Such a stimulus produced by phytoplankton in order to induce spawning is hardly conceivable in the case of *Pandalus borealis*. The latter spawns generally late in autumn when the phytoplankton production is limited or has ceased altogether. However, the hatching of the prawn eggs takes place in spring. In northern localities and in threshold fjords the hatching is retarded. In most localities the prawn larvae seemingly escape at a time of the year when the particular region is rich in phytoplankton. It can hardly be assumed that the phytoplankton stimulus in any way determines the hatching of the prawn eggs. It is more probable that the temperature-time factor has a decisive influence on the duration of the ovigerous period and thereby on the date for the hatching of the eggs.

The variations in growth and maturing of the deep sea prawn will naturally influence the productivity and the renewal of the stock on the different prawn fields and thus also effect the commercial prawn fishery. In localities where the prawns have a low rate of growth they will become ovigerous relatively late in life and produce relatively few broods within a limited period of time, while in localities where the rate of growth is fast more broods will be produced within the same period. If a prawn field with a high reproductive ability should be overfished the prawn population here will recuperate within a relatively short space of time if properly protected, while a locality with a low reproductive rate would need longer time to become remunerative again. Influx of cold water on a prawn field over an extended period of time will probably also have a depreciating effect on the production of new broods and on the fishery.

The results of the investigations indicate that certain prawn fields, particularly in Northern Norway, hardly can stand the same fishing intensity over a longer period of time as for instance the prawn fields in Southern Norway. Any proposals as to enforcement of protective measures for local fjords and prawn grounds must be treated more or less individually. However, it lies outside the scope of the present work to deal with the problems of taxation and protection of the deep sea prawn in the different localities.

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